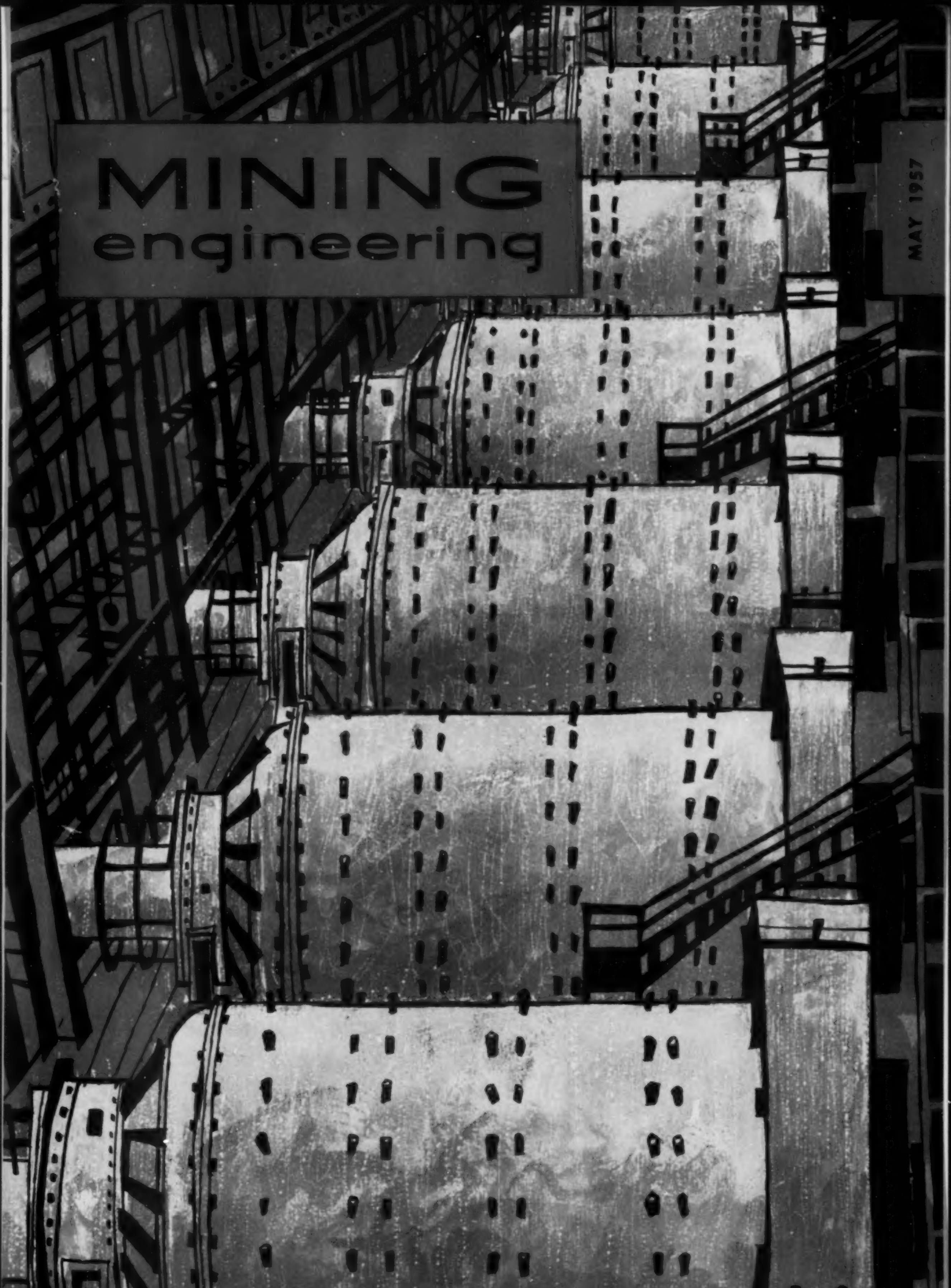
MINING
engineering
MAY 1957

The AIME also publishes **Journal of Metals** and **Journal of Petroleum Technology**

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MINING engineering

VOL. 9 NO. 5 MAY 1957

COVER

Artist Herb McClure uses a mill bay to symbolize large modern beneficiation plants. The electrical equipment that powers these plants is the subject of an article on page 529.

Know Your Society

ARTICLES

TRANSACTIONS

FEATURES

PERSONNEL

THE following employment items are made available to AIME members on a non-profit basis by the Engineering Societies Personnel Service, Inc. (Agency) operating in cooperation with the Four Founder Societies. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18;** 100 Farnsworth Ave., **Detroit;** 57 Post St., **San Francisco;** 84 E. Randolph St., **Chicago 1.** Applicants should address all mail to the proper key numbers in care of the New York office and include 6c in stamps for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service, to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter, $12 a year.

— MEN AVAILABLE —

Mining Geologist-Engineer, 33, single; three years experience property examination and appraisal, exploration division, AEC. Excellent recommendations. Five years underground engineering experience in tungsten and iron mining. Seeks opportunity for advancement in exploration, liaison, or management capacity with progressive organization. Willing to travel. Foreign or domestic. M-315-800-Chicago.

Management and Operation Engineer, B.S., 39; ten years mine management and engineering experience including outside consulting assignments; four years experience equipment maintenance mining, earth-moving, etc.; one year survey; one year instruction-graduate study and electrical transmission evaluation. Location desired, Northwest, West. M-316-San Francisco.

Mining Engineer, B.S. in geology, 41; 12 years experience mining engineer Lake Superior district and Central America. Open pit and underground. Experienced with both truck and rail pits. Available in 30 days. Location desired, South or Southwest. M-317-795-Chicago.

Engineer, B.S., 40; five years experience in mining engineering. Location desired, U. S., Canada, or South America. M-318.

Superintendent or Manager, any type of mining, B.S. in mining engineering, 40. Five years underground experience as engineer for large metal mining company, 1½ years exploration and production engineering experience, AEC; 1½ years exploration engineer for open pit, operator. Can handle men effectively. Prefer western U. S. M-322-San Francisco.

Geologist, M.A., 51, masters degree. Twenty-nine years experience, foreign and domestic; 20 years in mining development, exploration, and evaluation; nine years oil exploration experience with major companies and as consultant. Desires permanent affiliation with aggressive company, consulting, or investment group. Available short notice. M-323-802-Chicago.

Mining Geologist, B.S., 26; two years experience topographic surveyor U. S. Army; two years seismographic observer; three months underground as miner's helper; six months open pit experience as trackman and bankman. Location desired, eastern U. S. M-319.

Mining Engineer, B.S. in mining engineering, age 26; one year mining and milling experience; two years military construction management. Desires opportunity. Location, immaterial. M-320-794-Chicago.

Mine Superintendent, B.S. in geological engineering, age 43; three and one half years experience as general superintendent of mining company in Mexico; two and one half years mine engineer and superintendent of underground mine in states. Experience in mining, geology, efficient low-cost operations, and management. Has ability to handle personnel and knows modern mining methods. Location, immaterial. M-321.

— POSITIONS OPEN —

Mining Engineer, with production experience in Frasch-process sulfur mining or allied fields. Salary, $10,000 to $15,000 a year. Location, Mexico. F-4811.

Geologist or Mining Engineer, 40 to 50, to head up an exploration on a Bolivian concession. Should have worked in South America and speak Spanish. Salary, $12,000 to $15,000 a year. F-4644.

Mine Superintendent, mining engineering graduate, with about ten years experience in Latin America. Salary, $10,000 a year plus bonus and housing. Location, South America. F-4603.

Assistant Mine Superintendent, mining engineering graduate, with at least five years open pit and some underground experience, to supervise continuous operations covering stripping, transportation, warehousing, and general mine engineering. Salary, $7800 a year. Location, Caribbean area. F-4602.

Exploration Geologists or Mining Geologists, 25 to 45, from no experience to assistant project manager. **a)** *Assistant Project Manager,* with 8 to 15 years experience, to organize, plan, and direct a major exploration project. **b)** *Project Engineer or Geologist,* with 7 to 15 years practical experience in exploration. **c)** *Senior Engineer, Exploration,* with 5 to 12 years experience in exploration and development. **d)** *Engineering Exploration,* with two to three years experience in survey, geological, and/or topographic maps, tonnage, and grade estimates. Should speak Spanish or Portuguese. Locations, South and Central America. F-4578.

Exploration Geologist, required by well established company in United States for exploration program in Liberia. Alluvial and foreign experience desirable. Salary, open depending upon experience. F-4567.

Geologists. a) *Geologist,* young, with field experience in uranium or petroleum. Salary, $6000 to $8000 a year. **b)** *Senior Geologist,* with at least five years exploration and development experience in uranium, gas, or oil. Salary, $10,000 to $12,000 a year. Location, New Mexico. W-4549.

Engineers. a) *Exploration Geologist,* young, with at least two years foreign experience in metal fields covering diamond drilling, trenching, geochemical and geophysical prospecting. **b)** *Mining Engineer,* young, with production experience in underground gold or gold copper property. Salaries, $7200 to $8400 a year plus extras. Location, Philippines. F-4529.

Research Metallurgist, B. S., preferably with some graduate work, for flotation beneficiation of low-grade uranium ores. Western university campus. Salary, $5000 to $7200 a year depending on training and experience. Must be U. S. citizen. W-4026-S-2612.

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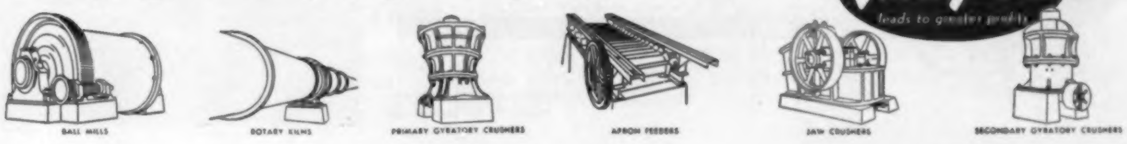

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Available in four standard sizes from 1 to 4 ft. in width the DSM Screen can provide from 200 gpm per ft. width of 48 mesh undersize to 500 gpm per ft. width of 8 mesh undersize.

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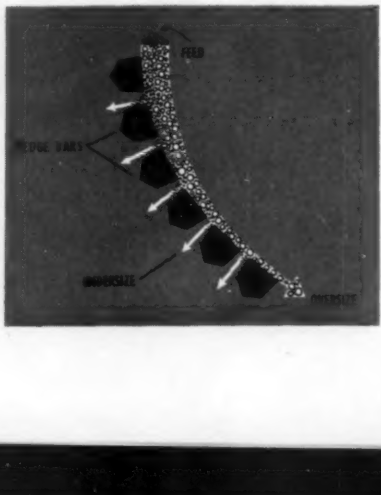

Illustrative drawing showing principle of separation

BOOKS

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Engineering Enrollment in the United States, ed. by Norman N. Barish, *New York University Press,* Washington Square, New York 3, N. Y., 226 pp., $7.50, 1957.—This volume presents basic statistics on enrollment trends in engineering education, with suggestions concerning future qualitative and quantitative needs. In addition to sections on aeronautical, ceramic, chemical, geological, metallurgical, and mining engineering, a chapter on engineering training in the USSR is included. •

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Sedimentary Rocks, 2nd Edition, by F. J. Pettijohn, *Harper & Brothers,* 720 pp., $12.00, 1957.—This volume is a complete revision of the first edition, comprising new discoveries in depositional environments, the mapping of vector properties, and geochemical evolution. Chapters on turbidity currents, sedimentary framework, paleocurrents, and sedimentary geochemistry have been incorporated into the original text and expanded illustrative material is included, as well as bibliographies and tables. •

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American Institutions and Organizations Interested in Asia, published by *Taplinger Publishing Co. Inc.* for the Conference on Asian Affairs Inc., 341 Lexington Ave., New York 16, N. Y., $7.50, approx. 500 pp., 1957.—A comprehensive reference guide to over 600 programs of institutions and nonprofit organizations with activities, staffs, and affiliations in Asia. Special appendices include a directory of American consular and diplomatic posts in Asia, and Asian embassies, consulates and information services established in the United States. •

(Continued on page 496)

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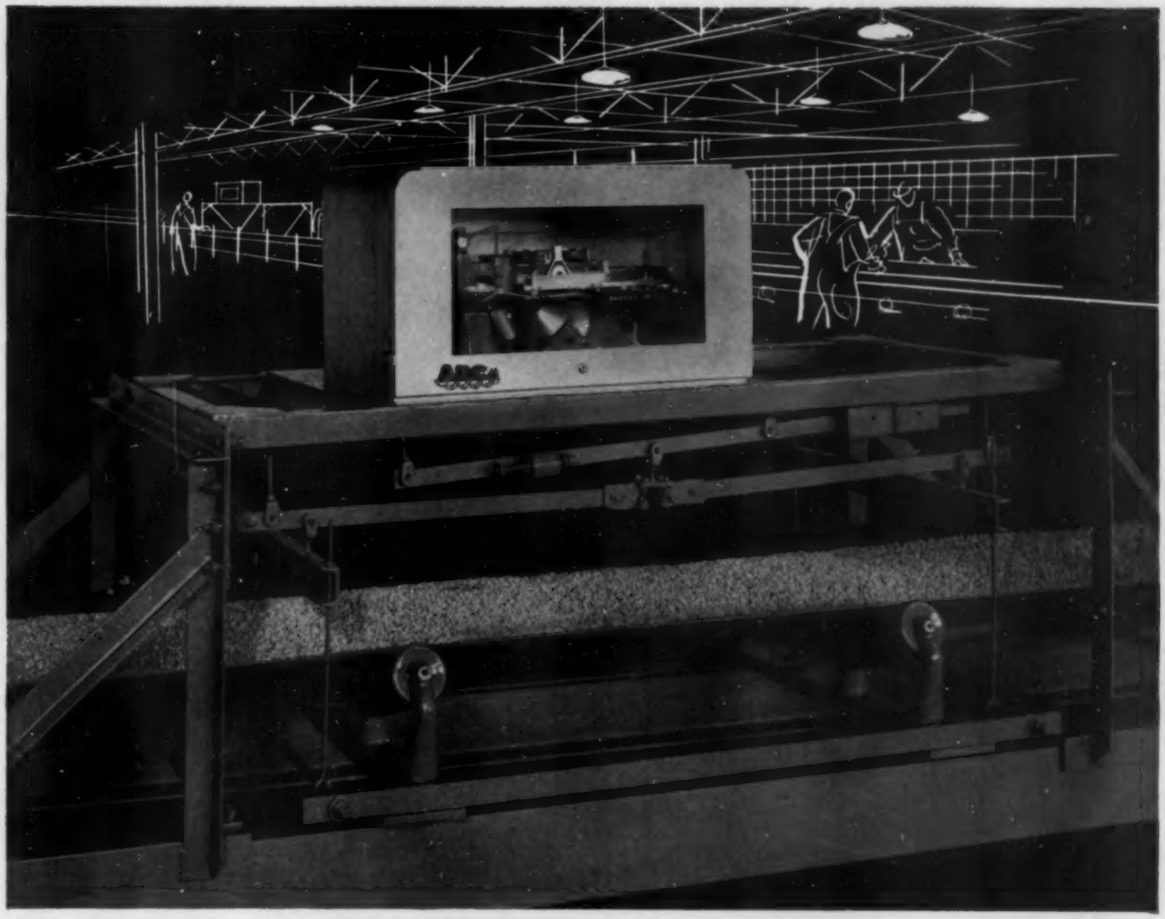
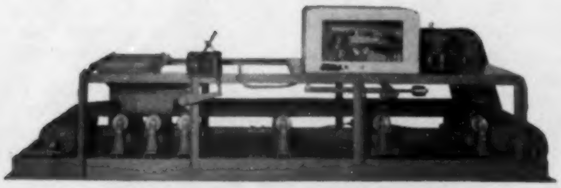
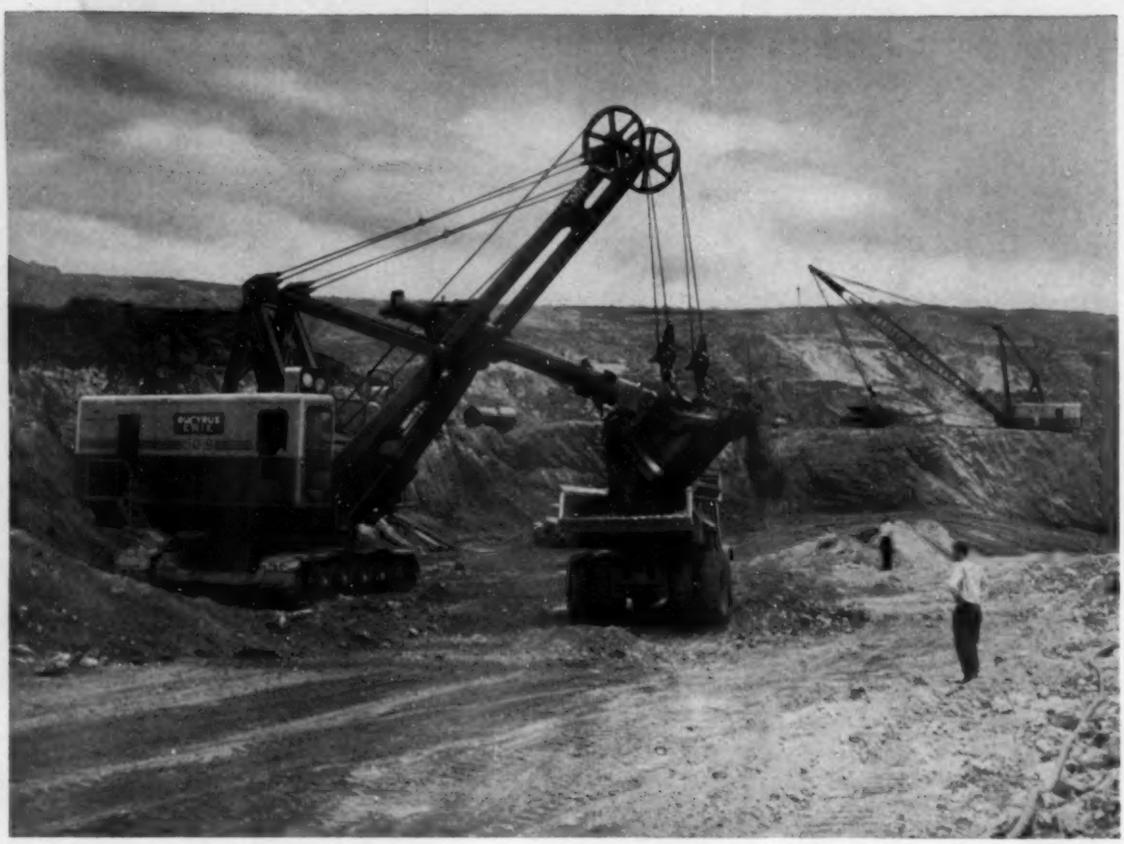




ON THE RANGE...more ore is mined with BUCYRUS-ERIE ELECTRIC SHOVELS than with any other make



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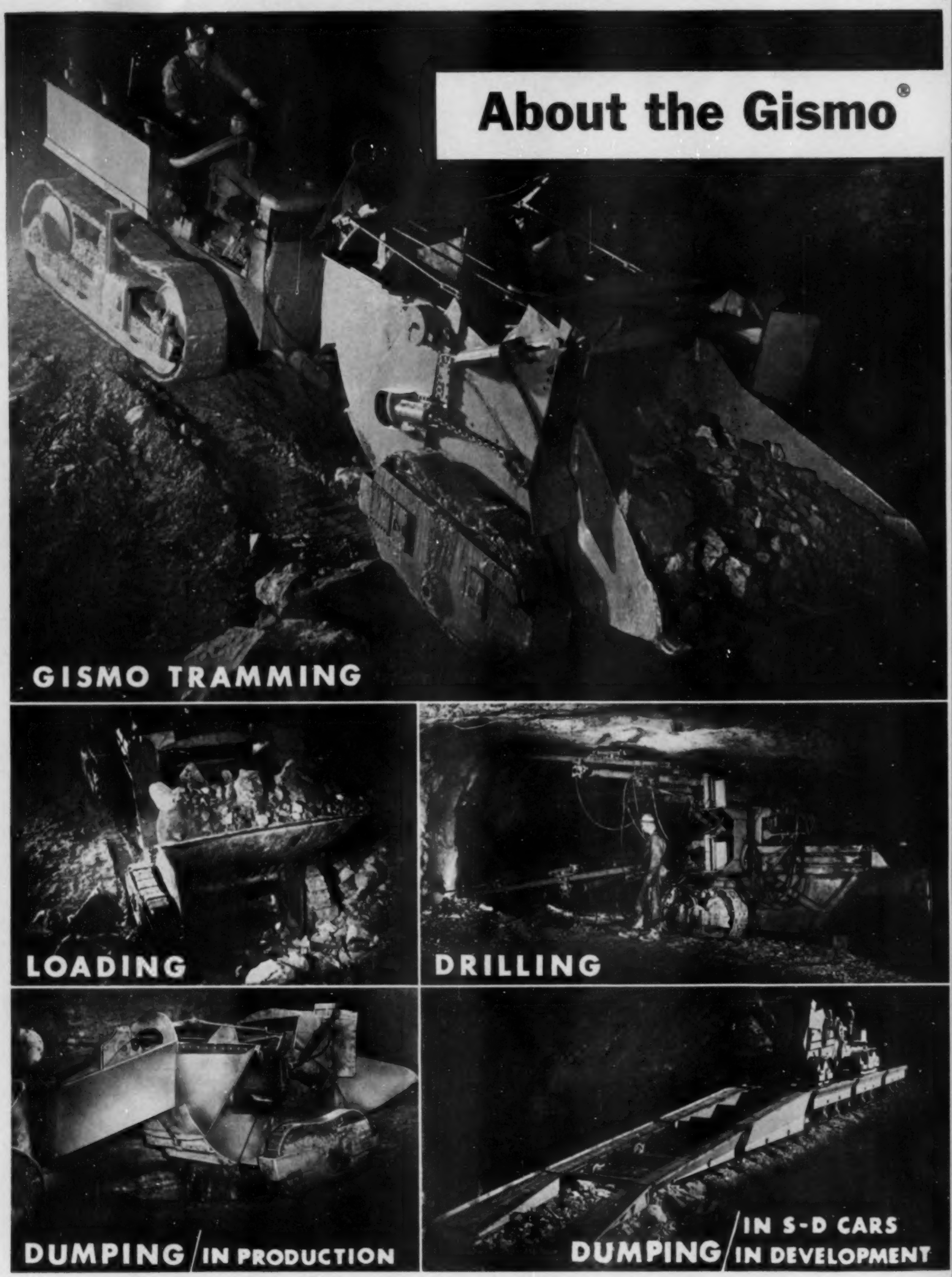
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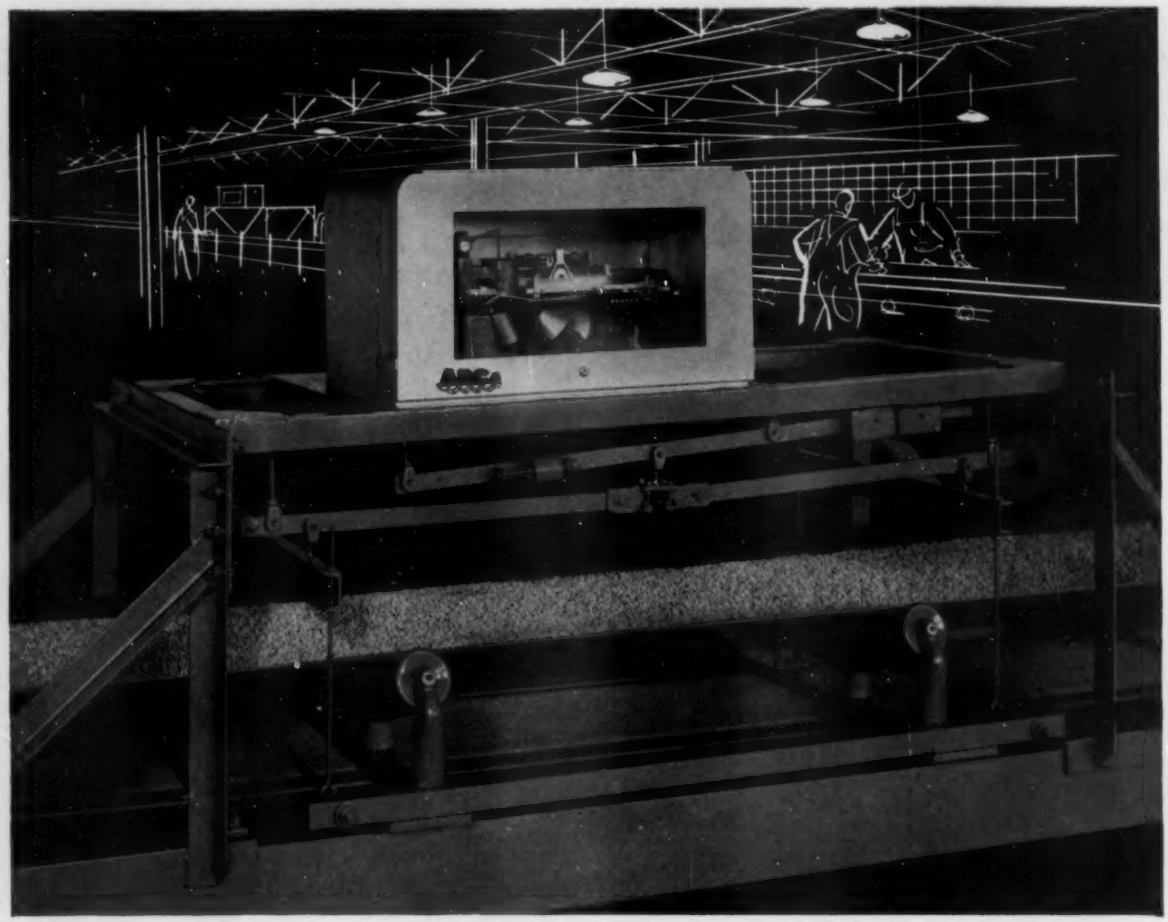

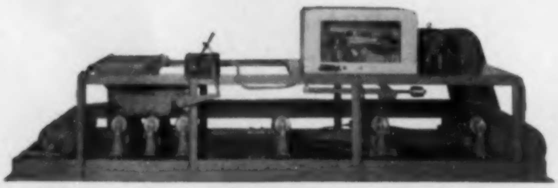

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360
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Books

Pipe Frame Conveyor

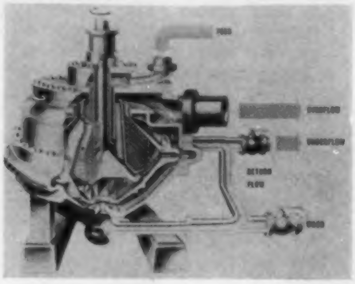
Prefabricated components, easily assembled in the field, are a feature of the Ready-Span pipe frame truss belt conveyor system by *Joy Mfg. Co.* Sections of various lengths are bolted together in any arrangement to make up required length. All accessories—idlers, walkaways, cover decking, hoods, supports, and special items—are clamped to pipe where needed. **Circle No. 1.**

Saw Tooth Bit

A tungsten carbide insert core bit by *Hoffman Bros. Drilling Co.* is claimed successful in coring coarse-grained sandstone, shale, slate, limestone, and similar material. The sintered bits are available in a variety of sizes with 4 to 12 segments. Low initial cost and good penetration are featured. **Circle No. 2.**

Pressure Centrifuge

Dorr-Oliver Inc. has the first commercial centrifuge for high pressure operation. A nozzle-bowl type unit, the centrifuge will perform high pressure, high or low temperature separations without reducing to atmospheric operating conditions. Two sizes are offered: PC-30 (shown) ranges 40 to 250 gpm; laboratory model PC-9 ranges 1 to 20 gpm. **Circle No. 3.**



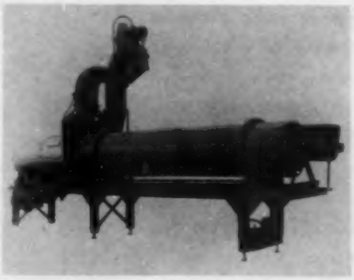
Automatic Buckets

Series A automatic dragline buckets by *Page Engineering Co.* are offered in capacities from ½ to 3 cu yd. Features include one-piece bottom plate, improved lip, two-position hitchplate, flared sides, forward arch,

reversible tooth points, and heat treated alloy steel hoist and load chains. The 1-yd bucket shown is one of a line of 33 models available in light-medium, general purpose, and heavy duty classes. **Circle No. 4.**

Rotary Dryer

A compact dryer for handling granular material without loss of fines is offered by *Carpco Mfg. Inc.* Concentric fire-tube design causes gases to travel the full length of the dryer before contacting feed. Two Dual-Flow models are available—one will evaporate 200 lb of water per hr, the other 400 lb per hr. Both are furnished complete with oil burner, primary air blower, automatic temperature control, indicating pyrometer, exhaust blower, dust cyclone, positive displacement feeder, and gear motor drive. **Circle No. 5.**



Optical Transit

Circles are read to 1 min directly and to 20 sec by interpolation in the Wild T-16 optical transit. Unit, by *Wild Heerbrugg Instruments Inc.*, incorporates an optical plummet giving an upright image. Optional attachments include a battery box for illumination of circle readings, horizontal and collimation level vials, and telescope reticle. **Circle No. 6.**

Shaft Sinker

Le Roi Div. of Westinghouse Air Brake Co. has a new shaft sinker, Model SDR, with air motor feeds and air motor-controlled booms. One master air line feeds a choice of two, three, four, or six booms and six different drills. Individual controls on each boom and drill are located according to customer specifications. Drilling area diameter is 26 ft with arms extended and sinker closes to 11 ft 6 in., but drills can be toed in to drill next to the 4-ft diam pedestal. Height of the SDR is 18 ft 6 in. **Circle No. 7.**

Portable Drill

Pennsylvania Drilling Co. has a compact drilling unit said to combine desirable features of three drilling methods: augering, driving, and core drilling. Testborer will auger to 150 ft, drive pipe and casing to 150 ft, drive soil samplers, and core drill to

300 ft with 3-in. bit. Trailer-mounted unit has a 6-ft hydraulic feed 4-speed rotary unit, 4-speed hoist, integral 19-ft derrick, and an automatic driving mechanism. Augering and driving operations are shown above. **Circle No. 8.**

Food Afield

Good meals during jobs in the field means better work turned in according to *Bolton Farm Packing Co.* Given details on food needs, the company will supply custom packages of high energy, varied meals. Four basic ration packs are available: *Fly-Camp*—feeds two men for one day (three meals); *Canadian Basic*—feeds two men for a full week; *Surveyor*—a pocket-size package lunch for one man (with canned heat for hot food in cold weather); and *Canadian Bush Survival Ration*—an aircraft, canoe, or field cache packet of food and survival items. **Circle No. 9.**

(21) CO ANALYZERS: *Mine Safety Appliances Co.* has a 4-page folder

(29) CABLE SPLICING: Vulcanized, neoprene insulated cable splices

Books

(Continued from page 488)

Practical Dictionary of Precious Stones and Gems, by A. André, *Publications Minieres et Metallurgiques,* 86 rue Cardinet, Paris 17°, France, approx. $1.62, 1956.—This book presents a catalogue of precious stones and their physical characteristics, including tables of hardness, specific gravity, refraction, chemical composition, and general background. The second part gives an account of the production of synthetic stones and the basis of distinction between synthetic and real jewels. A bibliography on synthetic stones is provided.

150 Years of Service, 1807-1957, Sesquicentennial Celebration, Coast and Geodetic Survey, U. S. Government Printing Office, Catalog No. C. 4.2: Se 7, Div. of Public Documents, Washington 25, D. C., 32 pp., 30¢, 1957.—A brochure noting activities of the Coast and Geodetic Survey. Illustrated.

Diamond, by Emily Hahn, *Doubleday & Co. Inc.,* 314 pp., $3.95, 1956.—A stimulating account of the finance and politics of the industry, mining techniques, and fashions in gem cutting, by "the world's prettiest mining engineer."

A new enlarged and revised book is now available covering examinations given by the State of California for the registration of civil engineers and engineers in training. The examinations, with solutions of problems appearing in 1940-1949 exams, comprise 381 pages, and copies are available from the author: August E. Waegemann, 2833 Webster St., San Francisco 23, Calif., at a cost of $7.00. •

NEMA Standards Publication: Mining and Industrial Electric Locomotives, *National Electrical Manufacturers Association,* 155 E. 44th St., New York 17, N. Y., $1.75, 48 pp., 1956.—A compilation of practical information on the rating, construction, motors, and control equipment of trolley, storage-battery, and combination-type mining electric locomotives.

Phase Diagrams for Ceramists, by Ernest M. Levin, Howard F. McMurdie, and F. P. Hall, *The American Ceramic Society,* 4055 N. High St., Columbus 14, Ohio, $10.00, 286 pp., 1956.—A compilation of over 800 diagrams classified in the following groups: metal oxide systems; systems containing nonmetallic oxides; systems containing halides, sulfides, etc.; and water-containing systems. Sources of the diagrams are indicated, and indexes by authors and constituent oxides or materials are provided. An introductory section includes definitions, a selected bibliography, and a general discussion of phase diagrams and their interpretation. •

(34) CUTTING EVAPORATION LOSS: Agile Mini-Vaps, expanded

(40) TUBING: Bulletin TB-340A is a guide to the choice of seamless

(46) MINE FANS: Catalog 901 from *Jeffrey Mfg. Co.* gives mine ventila-

(21) CO ANALYZERS: *Mine Safety Appliances Co.* has a 4-page folder on continuous carbon monoxide analyzers. The 2, 5, and 8-point units permit centralized control for a widely scattered area and may be used with direct-reading meters, continuous recorders, and automatic warning or control devices.

(22) BRIDGE CRANES: The B-47 hand traveling crane in capacities of 3 to 10 tons with spans up to 50 ft is available from the Wright Hoist Div. of *American Chain & Cable Co.* Bulletin DH-459A gives details on construction, weights, dimensions.

(23) SAMPLE SPLITTERS: A bulletin describing a line of splitters designed for sampling fine materials is offered by *Carpco Mfg. Inc.* The three standard models illustrated are constructed with stainless steel blades. All solder joints and other material traps have been eliminated.

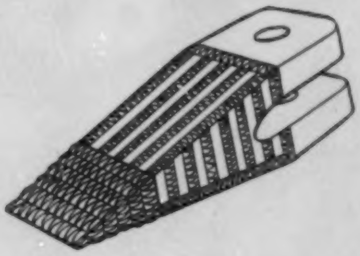
(24) COAL BITS & HOLDERS: Carbide-tipped bits and block holders, said to increase efficiency of barrel-type coal recovery auger heads while reducing bit costs and changing time, are available from *Austin Powder Co.* Provided with tapered shanks, the bits drive-fit into conical holders. Vibration and chattering with resultant shank breakage are claimed almost eliminated because no lugs are used. According to the manufacturer, all 21 bits on the outer cutting circumference of a 42-in. machine can be changed in approximately 3 min, using only a hammer and punch.

(25) SCRAPERS: Three new scrapers and a new overhung engine bottom dump are detailed in data sheets from *Euclid Div.,* General Motors Corp. Models SS-18 and SS-24 are 4-wheel 300-hp tractor type scrapers with struck capacities of 18 and 24 yd. Model S-12 is a tractor and semi-trailer combination with 24 yd capacity. Power is supplied by two engines—300 hp for the tractor and 218 hp for the scraper axle.

Free Literature

(26) POWER RATING CHART: A 4-page folder from *International Harvester Co.* contains a rating chart for the 17 IH engines and power units. Brake hp ratings are corrected to standard conditions. Ratings are given on all fuels which can be used in the carbureted units.

(27) HARD-FACING: Six all-position hard-facing and manganese electrodes offered by *Sight Feed Generator Co.* are claimed to cover almost all buildup and hard-facing applications in the mining, quarrying, crushing, processing, and earthmoving industries. A 20-page manual illustrates applications and recommends procedures.



(28) REAR DUMPER: *Koehring Co.* has a new 24-page illustrated bulletin detailing features of the 8x8 ft 6 yd Dumptor. Streamlined all-steel body has a heavy kick-out pan to help break suction when unloading wet or sticky material. Dumptor travels round trip without turning by shuttling between loading unit and dump area. It is claimed to operate with equal ease and speed in both directions.

(29) CABLE SPLICING: Vulcanized, neoprene insulated cable splices without power loss may be done, in the plant or in the field, with a portable kit by Cam-Lok Div., *Empire Products Inc.* Crimping press, cable cutter, and vulcanizing mold are used for splices that are flexible, waterproof, and shockproof. Bare cable ends are crimped within a copper tube which is in turn covered with two protective sleeves.

(30) BELTS: A new catalog from *Raybestos-Manhattan Inc.* covers heavy duty conveyor belts. Given are tension ratings for vulcanized and metal splices, minimum recommended pulley diameters, and minimum widths for good troughing. Included is data on a line of hot material belts for temperatures from 150° to 350°F.

(31) DIAPHRAGM CONTROL VALVES: Two new folders from *Minneapolis-Honeywell Regulator Co.* give data on single and double-seated Series 800 diaphragm control valves. Pneumatically controlled, the units will control liquid, gas, and steam flow under a wide range of operating conditions.

(32) PORTABLE HOISTS: *Joy Mfg. Co.* offers a new 12-page booklet describing single drum multi-purpose hoists. Ranging in size from 0.9 to 15 hp, the hoists have lifting capacities from 750 to 5000 lb at rope speeds up to 125 fpm. Wire rope capacities range 200 to 1500 ft. Joy hoists are available in air, electric, and gasoline driven models.

(33) HAULER CAB SHIELD: A new tapered sideboard and load-carrying cab shield, said to improve load distribution, is offered by *Galion Allsteel Body Co.* Designed for use on Galion N and NF series dump bodies with front mounted telescopic hoists, the sideboards and cab shield permit over-the-cab loading. This is said to shift the load center of gravity forward, placing more weight on the front axle.

MAIL THIS CARD

for more information on items described in Manufacturers News and for bulletins and catalogs listed in the Free Literature section.

5

Mining Engineering **29 West 39th St.** **New York 18, N. Y.**

Not good after August 15, 1957—if mailed in U. S. or Canada.

Please send { More Information ☐ / Price Data ☐ / Free Literature ☐ } on items circled.

Name ______ Title ______

Company ______

Street ______

City and Zone ______ State ______

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
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41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64						

Students should write direct to manufacturer.

(34) CUTTING EVAPORATION LOSS: Agile Mini-Vaps, expanded polyethylene floats which cut evaporation loss of open liquids, are detailed in a catalog sheet from *American Agile Corp.* The chemical-resistant floats are contoured to interlock and cluster at the surface of volatile solutions. Prices are included.

(35) POWER UNITS: *Detroit Diesel Engine Div.* of General Motors has a 19-page catalog outlining its complete line of power units for all types of industry use. Specifications are given on 31 engine models ranging 44 to 761 brake hp. Data is included on a new 6-cyl Turbopower engine.

(36) DUST COLLECTOR: The Aerodyne dust collector has been added to products made by *Research-Cottrell Inc.* A cone-shaped louvered steel sheet forms the filter surface. Dust is separated out by aerodynamic force. Unit takes little space and may be installed in any position.

(37) AIR CONTROL VALVES: A 71-page data file on the Starline valve series is offered by *Ross Operating Valve Co.* The line comprises a group of five pilot heads which are interchangeable with seven valve bodies. The file includes flow diagrams, a list of parts, and a price list.

(38) CONCRETE COMPOUNDS: *Sika Chemical Corp.* offers details on a line of compounds for improved concrete and mortar and better concrete protection and sealing. Bulletin Si-5 contains brief descriptions of Sika products and tips on maintenance of concrete.

(39) CRUSHING, SCREENING, LOADING: Equipment by *Universal Engineering Corp.* for crushing, screening, washing, loading, and conveying is detailed in Catalog CC 1-56. Included are Bulldog hammermills, Wobbler feeders, Impact Masters, stationary aggregate plants, apron feeders, conveyors, and parts.

(40) TUBING: Bulletin TB-340A is a guide to the choice of seamless mechanical tubing from the Tubular Products Div., *Babcock & Wilcox Co.* Round, square, rectangular, or other shapes can be provided.

(41) WASHING & CLASSIFYING: A 44-page catalog, No. 55, from *Eagle Iron Works* is a comprehensive collection of data on the Eagle washing and classifying equipment for sand, gravel, crushed stone and ore. On-the-job photos, tables, flow diagrams, and charts supply valuable information. Individual requirement questions will be answered by using the tear sheet blank supplied.

(42) COAL DRYING: Low power requirements, uniform product, no oxidation, and greater safety are claimed to result from the use of the *Link-Belt Co.* Multi-Louvre dryers. Book 2609 gives typical layouts, dimensional data, and general information on drying, cooling, and processing of bulk materials.

(43) MANGANESE RODS & WELDMENTS: Amsco hardfacing alloys will keep dipper teeth, tractor treads, and crusher jaws out of the shop and on the job longer according to American Manganese Steel Div. of *American Brake Shoe Co.* Bulletin MN-56 shows how to handle manganese rods and weldments for top resistance to impact and abrasion. Also included is data on the MF semi-automatic welder and the Leader 550 automatic electric welder.

(44) PROCESSING MACHINERY: *Nordberg Mfg. Co.* details a part of its machinery line in Bulletin 244. Included are Symons gyratory, cone, and impact crushers; vibrating screens and grizzlies; mine hoists, skips, and cages; diesel engines; and track maintenance machinery.

(45) HYDRAULIC HOSE FITTINGS: Reusable Hoze-lok fittings for high pressure service hose are described in Catalog 4433 from *Parker Appliance Co.* Hose sizes range 3/16 to 2-in. ID.

(46) MINE FANS: Catalog 901 from *Jeffrey Mfg. Co.* gives mine ventilation data and shows typical arrangements and drives to suit various conditions. Jeffrey will supply multistage units for high-pressure, high-volume service; junior models for low pressure work; and midget blowers for auxiliary service.

(47) MINING MACHINES: *International Harvester Co.* offers an 8-page photo folder picturing their construction equipment at work in mining operations. Included is the new International Drott mining tractor, designed and equipped for underground operation.

(48) HEAVY MEDIA SEPARATION: *Ore & Chemical Corp.* has the OCC vessel for all heavy-media separating needs. Five basic models are available—capacities range to 400 tph. Simplicity is stressed in design, and a minimum of headroom and floorspace is required.

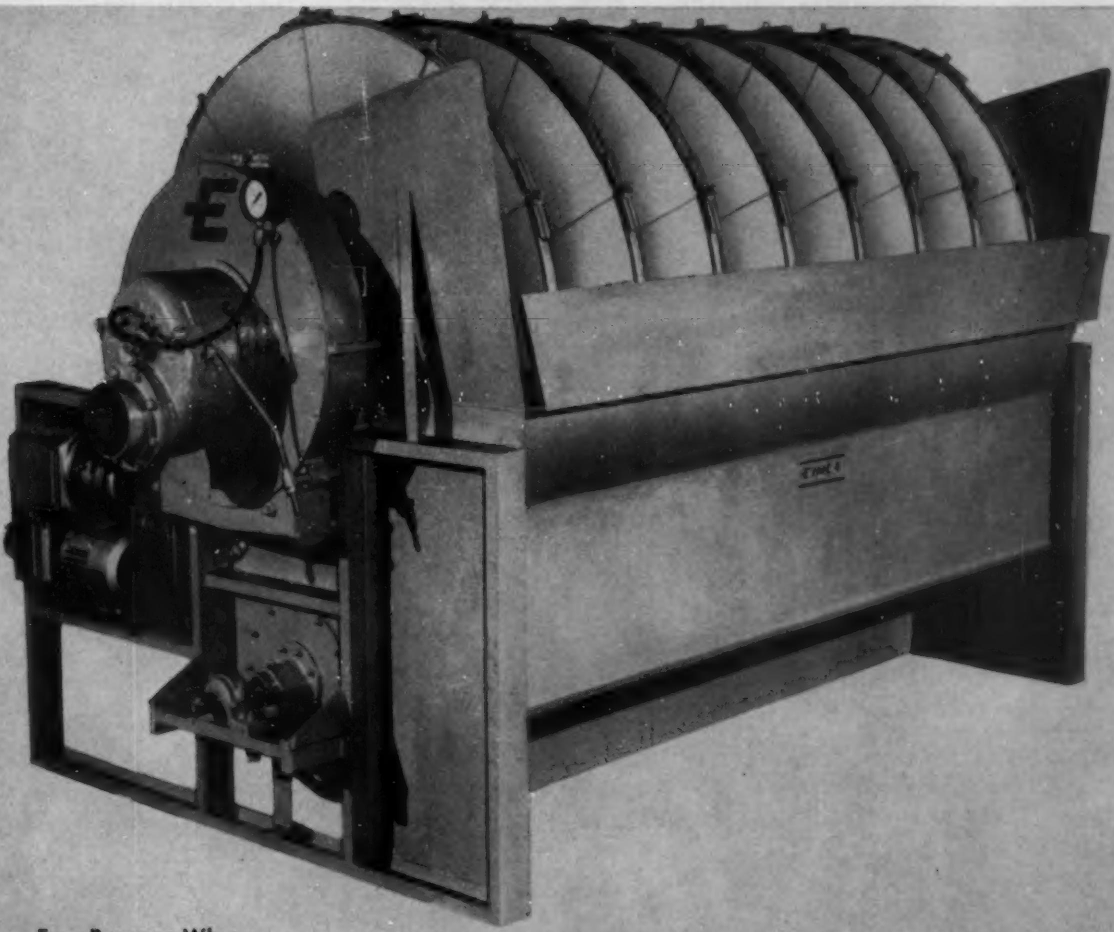
(49) THREADLESS BITS: Seven types of Liddicoat detachable drill bits are offered by *Western Rock Bit Mfg. Co.* All are fastened by drive fit and removed with knockoff blocks. Cutting edges are shaped for fast drilling and are not made for resharpening.

(50) WIRE ROPE SLINGS: New folders on suggested applications and ordering specifications for wire rope slings are available from Wickwire Spencer Steel Div. of *Colorado Fuel & Iron Corp.* Three types are described: Uniflex for resistance to severe abrasion; Multiflex for maximum load-bearing surface area and one-way flexibility; and Maxiflex for flexibility in all directions.

(51) CALCULATOR: An imported circular calculator of 3-in. diam is claimed to equal a 10-in. slide rule in performance. The aluminum Controller from *Silver Bells Ltd.* is pocket-size and lightweight.

(52) CHAINS & SPROCKETS: Pocket-size Bulletin 56-130 from *Chain Belt Co.* gives quick information on the Rex line of chains, sprockets, elevator buckets, belt idlers, bearings, flexible couplings, and spray nozzles. Rex Z-Metal buckets are recommended for handling gritty, abrasive bulk materials and such corrosive materials as wet coal, acidulated phosphate rocks, and dehydrated lime.

(53) DUMPERS: *Euclid Div.* of General Motors offers bulletins on four new rear-dump models. Specifications are given for the following units: Model S-7, an overhung engine type tractor with semi-trailer of 12-ton capacity; Model S-18, a semi-trailer with rated payload of 35 tons; Model R-18, a conventional hauler of 18-ton capacity; Model R-40, a tandem axle unit powered by two engines—capacity is 40 tons.



◆ 1903

1917 ◆

Designs Change in 53 Years...

...but DART QUALITY REMAINS

In the 53 year history of the Dart Truck Company, Truck designs have naturally undergone many radical changes (many of which were pioneered by Dart), but the quality, construction and serviceability of Dart Trucks has remained the same.

The popular Dart 35SL is an example of Dart's rugged quality. Its 400 H.P. diesel engine with downhill retarding hydraulic torque converter is conservatively rated at 35 tons (24 cubic yards, struck). Write for complete specifications.

Are You Going to the COAL SHOW?
Look us up at the
Upper Lakeside Hall
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POWER **for the Climb —** ***SPEED*** **for the Haul Road**
HEAVY DUTY TRUCKS ***EXCLUSIVELY*** **SINCE 1903**

DART TONNAGE ENGINEERED TRUCKS

Kansas City 8, Missouri

SUBSIDIARY OF THE CARLISLE CORPORATION

129

(Above): *Four Nordberg 10½'x16' Rod Mills and eight Nordberg 10½'x14' Ball Mills installed in a large concentrating plant for the reduction of hard, abrasive "Taconite" ore.*

In the mining industry, thousands of service hours are required to prove true dependability . . . a significant reason why Nordberg Grinding Mills now are being selected for installation in many large ore reduction plants.

Nordberg Grinding Mills are designed and built for wet or dry grinding of metallic and non-metallic minerals. Sizes range from 6 to 13 feet diameter and up to 50 feet in length in Rod, Ball, Pebble, Tube and Compartment types.

Of advanced engineering and quality construction, Nordberg Grinding Mills assure trouble free and low cost operations. Consult an experienced Nordberg engineer next time you have a grinding problem. *NORDBERG MFG. CO., Milwaukee, Wisconsin.*

SEND FOR THIS
NEW BULLETIN

This new Nordberg Bulletin 232 fully illustrates and describes the full line of Nordberg Grinding Mills for the efficient, low cost processing of ores and industrial minerals. Write for your copy today.

SYMONS . . . A registered Nordberg trademark known throughout the world

NORDBERG MACHINERY

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CRUSHERS SYMONS SCREENS NORDBERG

MACHINERY FOR PROCESSING ORES and INDUSTRIAL MINERALS

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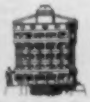
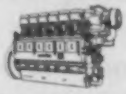

Symons Gyratory and Cone Crushers



Mine Hoists


Symons Vibrating Grizzlies and Screens


Diesel Engines

GM157

Sign Long Term Jamaican Bauxite Contract

Reynolds Metals Co. and its wholly-owned subsidiary, Reynolds Jamaica Mines Ltd. have signed a contract with the Government of Jamaica guaranteeing the right to mine bauxite for 99 years on all lands now owned or under option and establishing ore royalties and taxes for 25 years. Reynolds Jamaica has acquired about 60,000 acres of bauxite properties since 1944. A royalty of 42¢ a long dry ton will be paid on the first 2 million tons shipped each year and 28¢ on each ton exceeding that amount. The company plans to ship at a rate of more than 2 million tons this year.

Plans Set for Ungava Copper-Nickel Area

After two years of discovery and exploration work in the Cape Smith area of Ungava, Quebec, arrangements have been made for development. The group of Canadian companies that prospected the area will retain a 50 pct interest; American Smelting & Refining Co. will take over the properties, provide necessary exploration funds, and if results permit, place the lands in production.

Newmont and Empire Star Agree on Merger

Empire Star Mines Co. Ltd. will merge into Newmont Mining Corp. on approval by stockholders this month. Newmont is principal stockholder of Empire Star which owns mining properties in California and has engaged in exploration. Two of its holdings, the Empire and North Star gold mines, halted operations in July 1956.

Uranium—South African Production . . . Stockpile for U. S.?

The Union of South Africa produced 4440 tons of U_3O_8 in 1956 and the Atomic Energy Board in Pretoria expects output of more than 5000 tons a year when all 29 uranium-producing gold mines reach intended capacity; 24 are now in various production stages . . . . AEC has indicated readiness to support legislation for a U. S. stockpiling program that would assure a continued high market for producers until 1966. A new bill introducing the measure leaves the amount of stockpile undetermined.

More Titanium Slag from Quebec . . . New Plant in Mexico

Production of titanium dioxide slag by Quebec Iron & Titanium Corp. will increase by 60 pct with the addition of new furnaces and auxiliary equipment at the Sorel, Quebec, processing plant. The new facilities call for spending more than $16 million . . . . The Mexican affiliate of Republic Steel Co. is making plans for a new titanium processing plant at Pluma Hidalgo on the Gulf of Tehuantepec.

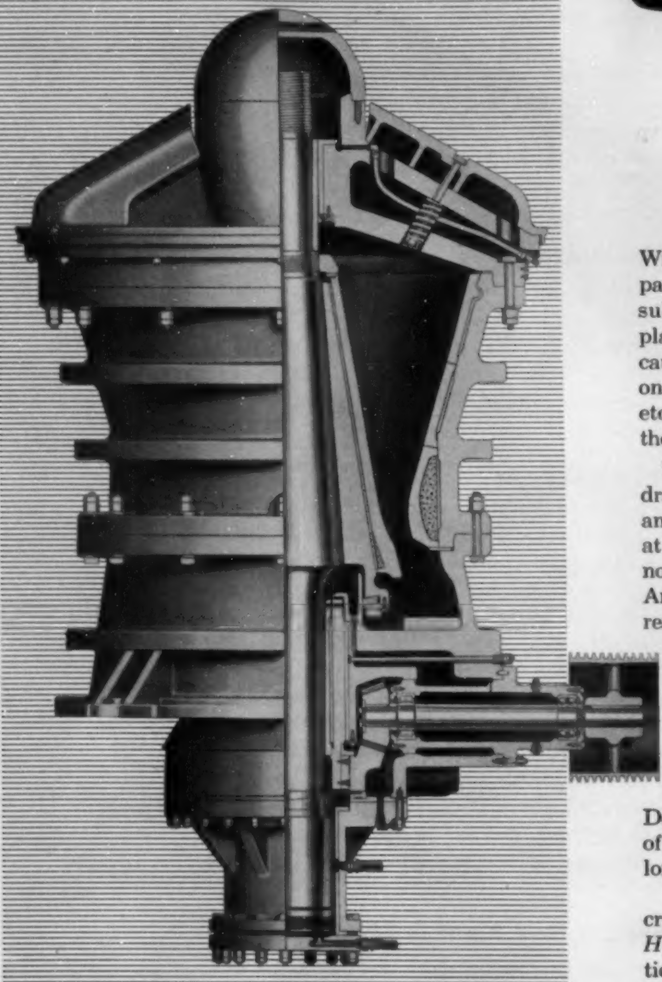
Study Alumina Reduction Works for Peru

Cerro de Pasco Corp. is investigating a combination plan for a power plant with an ultimate potential of 750,000 kw at Mantaro Bend, Peru, coupled with an aluminum works near the Bay of Paracas. Hydroelectric development alone would cost approximately $200 million. Mantaro River power would be tapped 180 miles inland, and transmitted to the coast. Alumina would be imported from outside sources.

Superior CRUSHER with Hydroset mechanism

Sets the pace

for your entire production circuit



With a *Superior* primary crusher setting the pace — *a fast pace* — you get the most out of subsequent equipment in your flow. Over-all plant operating costs are kept at a minimum because the entire circuit remains in balance. Secondary and tertiary crushers, vibrating screens, etc., may be utilized in sizes and types to meet the requirements of a constant tonnage.

The secret is in the *Hydroset* control. This hydraulic adjustment maintains the initial setting and a uniform product by compensating for wear at the flip of a switch. Related equipment need not be readjusted to meet variations in feed size. And — if the *Superior* crusher stops under load, restarting is facilitated by *Hydroset* control.

Ask for Bulletin 07B7870.

Hydroset mechanism reduces maintenance

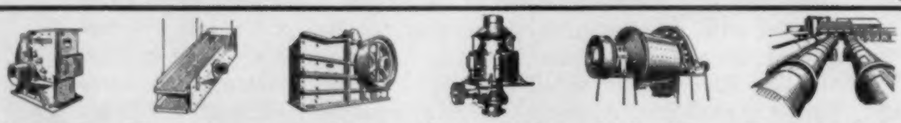
Downward thrust, gyrating and rotating motion of mainshaft are carried on efficient, oil-cooled, long-wearing step bearings.

Remember, only an Allis-Chalmers gyratory crusher offers the profit-building advantages of *Hydroset* mechanism. For complete information, see your A-C representative or write Allis-Chalmers, Industrial Equipment Division, Milwaukee 1, Wisconsin.

Superior and Hydroset are Allis-Chalmers trademarks.

ALLIS-CHALMERS

A-5323



Hammermills | Vibrating Screens | Jaw Crushers | Gyratory Crushers | Grinding Mills | Kilns, Coolers, Dryers

Paucartambo Power For Zinc Refinery in Peru

Goal is 87,000 Tons Per Year

Cerro de Pasco's long-range zinc development program was brought a step closer to completion with the dedication, on March 17, of new hydroelectric power production and transmission facilities in eastern Peru.

With the additional power now flowing over the 89-mile, 138,000-v transmission line connecting the new Yaupi Bajo power station with the Cerro de Pasco smelting and refining center at La Oroya, zinc production will be expanded from a current daily rate of 120 tons of slab zinc to 150 tons by the end of the year.

The project was begun in 1951 and cost $25 million. Water of the Paucartambo River, which has its source in the snow-capped Peruvian Andes, was harnessed to provide a 72,000 kva facility. The station will provide sufficient additional power for full operation of existing metal refining plants even in years when rainfall in the region is abnormally low.

Out of the tunnel comes this 3800-ft penstock conducting water to powerhouse 1500 ft below. There it branches out into three tubes, each supplying a single turbine.

Shown are Cerro de Pasco's principal operating properties in Peru. Yaupi (circled, upper right) is the eastern terminus of a water diverting tunnel and site of the new power station. Substations are provided at Carhuamayo and Oroya.

River water has been dammed at a section of the Paucartambo Valley known as Yuncan. From this headworks the water is diverted into a horseshoe-shaped 8-mile tunnel bored through the mountains and then charged down a 3800-ft steel penstock to the power station at Yaupi Bajo.

The powerhouse, located on the right bank of the Paucartambo 11 miles downstream from the Yuncan Dam, houses three generators, each rated 24,000 kva. With the development of a relatively small water storage area, it is possible that a fourth and probably a fifth generating unit may be added to the power plant, increasing its capacity to more than 100,000 kva.

To supplement the water available from the Paucartambo during the dry season, water is diverted into the main tunnel from the Manto River by a concrete arch dam, diversion tunnel, and connecting raise. Plans also are underway to divert the water of the Santa Isabel River into a reservoir feeding the Yuncan Dam.

(Continued on page 512)

EURATOM, a newly created European atomic pool for the development and use of atomic energy, has set for itself an ambitious goal of 15,000 megawatts of power by the end of 1967. The six nations involved—Belgium, France, Western Germany, Italy, Luxembourg, and the Netherlands—will collectively spend $200 million in the first five years through a commission which will act much as the AEC does in the U. S. Main activities will concern supply, inspection, and international relations.

Reactor construction will be left to the work of the member countries, but the atomic pool will create a common or free market for nuclear material and equipment, encourage research coordinated against wasteful duplication, and maintain a reserve corps of technicians to serve all the members.

Assistance from outside countries will be necessary in reaching Euratom's goal. F. Etzel, vice president of the European Community for Coal & Steel, notes that "our countries produce only small quantities of natural uranium and no enriched uranium. Because we will want to base at least an important part of our program on reactors requiring enriched uranium, we can do it only if we can be sure of a supply from the U. S. during the critical early years...

"Again Europe needs your help, but this time we will build a two-way street. Our relationship will not be that of one country giving and another receiving, but of two great united nations, the United States of America and the United States of Europe, working in association to the mutual benefit of themselves and the world."

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COBALT has followed the track of lithium and the American Lithium Institute with announcement of the formation of the Cobalt Development Institute in Belgium. Made up of the world's major cobalt producers, its object is also to improve existing uses and to develop new ones.

The Belgian *Centre d'Information du Cobalt* in Brussels has been entrusted with the execution of the program. The center is represented in the U. S. by the Cobalt Information Center at the Battelle Memorial Institute in Columbus, Ohio. A research program of fundamental studies is being sponsored and, through the dissemination of technical data, these centers will assist users and potential users of cobalt.

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AN 11-fold increase in imports of iron ore since the end of World War II was established with the record 34 million tons imported last year. Since 1946, when the total was 3.1 million tons, imports have gained in every year but one.

American Iron & Steel Institute points out that these gains are mainly the result of exploration and development programs by American firms, especially in Canada and Latin America. The three largest of 18 foreign iron ore sources last year were: Canada, 15.4 million net tons; Venezuela, 10.4 million net tons; and Peru, 2.0 million net tons.

Many major firms have new iron ore projects, or at least prospects, cooking on domestic fires. In addition to the Missouri activity by four companies noted in the news section of this issue, there is exploration work being done in the Butternut District of Wisconsin. Cleveland-Cliffs Iron Co. says that a large part of their 1956 capital expenditure of more than $6.5 million was spent on the development of a program for beneficiation of low grade iron ore. Bethlehem Steel Co. reports that the Erie Mining Co. taconite project in Minnesota will be in full operation by spring, 1958—at capacity of 7.5 million gross tons per yr. Limited pellet production will begin shortly before the end of this year.

Upgrading of marginal ores instead of direct shipping is forced by the demands of steelmakers. A major reason is the high cost of building new blast furnaces. Steelmakers want top production efficiency from existing units.

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WE did a double take the other morning and almost skipped back out of the office thinking we had stepped into the wrong publications department on seeing a neat yellow paperbound book bearing the doubtful title, *Control of Radon and Daughters*. On looking closer, however, we found that it was not only innocent but a valuable piece of free data from the Public Health Service. It describes results of a long range study of radon and daughter products in uranium mines covering methods of measuring atmospheric concentrations, establishing a safe working level for these products, and developing effective control measures.

Copies of the report (Public Health Service Publication No. 494) are available from the Occupational Health Program of the Public Health Service, U. S. Dept. of Health, Education, & Welfare, Washington 25, D. C.

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ONTARIO registered an all-time high for mineral production with a 1956 total of about $641 million, nearly $50 million more than the previous record established in 1955. The Ontario Dept. of Mines notes in its annual report that the 1956 total was 30.99 pct of the mineral production for all Canada, which climbed to a total of $2,076,699,098 (exceeding the $2 billion mark for the first time).

"Probably never before in history has any one year seen so many mines hastening toward the stage of actual production . . . 1957 will give Ontario a whole host of new producing mines," states the report.

Almost 80 pct of the Ontario total came from the metal mines which produced 45 pct of all the metallic mineral values for the whole of Canada. Dollar-

wise the most important metal was nickel; second place was taken by copper. A production record was set by iron ore which increased by about a million tons over 1955.

Uranium is fast developing in the Blind River area. Within a radius of ten miles, two large uranium mines are in production, and construction is proceeding so rapidly on ten others that most of them will be in full operation by the end of 1957. The Consolidated Dennison mine alone is reported to have ore reserves of at least 136 million tons—more than double the combined reserves of all uranium mines in the U. S. The report puts the value of this tonnage at some $3.8 billion.

A total of 47,997 claims were staked during 1956 and by the end of the year there were approximately 105,000 in good standing. The emphasis, however, was on exploration and development. About 926,000 ft of hole was diamond drilled.

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EXPANSION of research and development programs of the U. S. Bureau of Mines, as proposed in its budget for the coming fiscal year, creates additional opportunities for engineers and scientists interested in government career positions. The Bureau is now seeking metallurgists, ore dressers, engineers (mining, petroleum, mechanical, and electrical), chemists, physicists, nuclear physicists, and qualified specialists in other technologies. Vacancies range from GS-5 ($4480 a year) to GS-12 ($7570 a year) and include some high level administrative and supervisory jobs. Applications may be directed to the Bureau's headquarters or to any of the following field installations of the Bureau of Mines: Tuscaloosa, Ala.; Juneau, Alaska; Tucson, Ariz.; Denver; College Park, Md.; Minneapolis; Rolla, Mo.; Reno or Boulder City, Nev.; Bartlesville, Okla.; Albany, Ore.; Bruceton, Pittsburgh, or Schuylkill Haven, Pa.; Rapid City, S. D.; Knoxville or Norris, Tenn.; Amarillo, Texas; Salt Lake City; Seattle; and Morganstown, W. Va.

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EMPLOYES at the Van Nuys plant of Lockheed Missiles need only a short training period to learn to feed mathematical problems encountered in their work to plant-installed electronic computers. To qualify, all an employe has to do is take a 12-hr course in programming. A knowledge of simple algebra is the only prerequisite.

A company official says the service will help employes with math problems too complex to be solved easily with desk computers and slide rules. It will also ease the work load of professional programmers, who can spend more of their time on highly technical problems.

To get in one day the answer to a problem that would take a week to solve by the usual means, the engineer will do it this way:

First, he states his problem as an equation. Next, he draws up a flow chart—an analysis of the problem as a series of computer operations. Then he fills out a coding sheet from which the computer's key punch operator takes instructions.

Finally, he checks the answer with a test case to which he knows the answer. He is taught diagnostic methods in the course through which he can find the trouble if there is an error.

The do-it-yourself computing service is the result of a new simplified coding technique called SOAP (for Symbolic Optimum Assembly Programming) developed by International Business Machines.

By using this technique, the novice programmer can write the actual equations on his coding sheet instead of the complex system of *address numbers* normally used to locate various pieces of information within the machine. This considerably simplifies both scientific and accounting problems.

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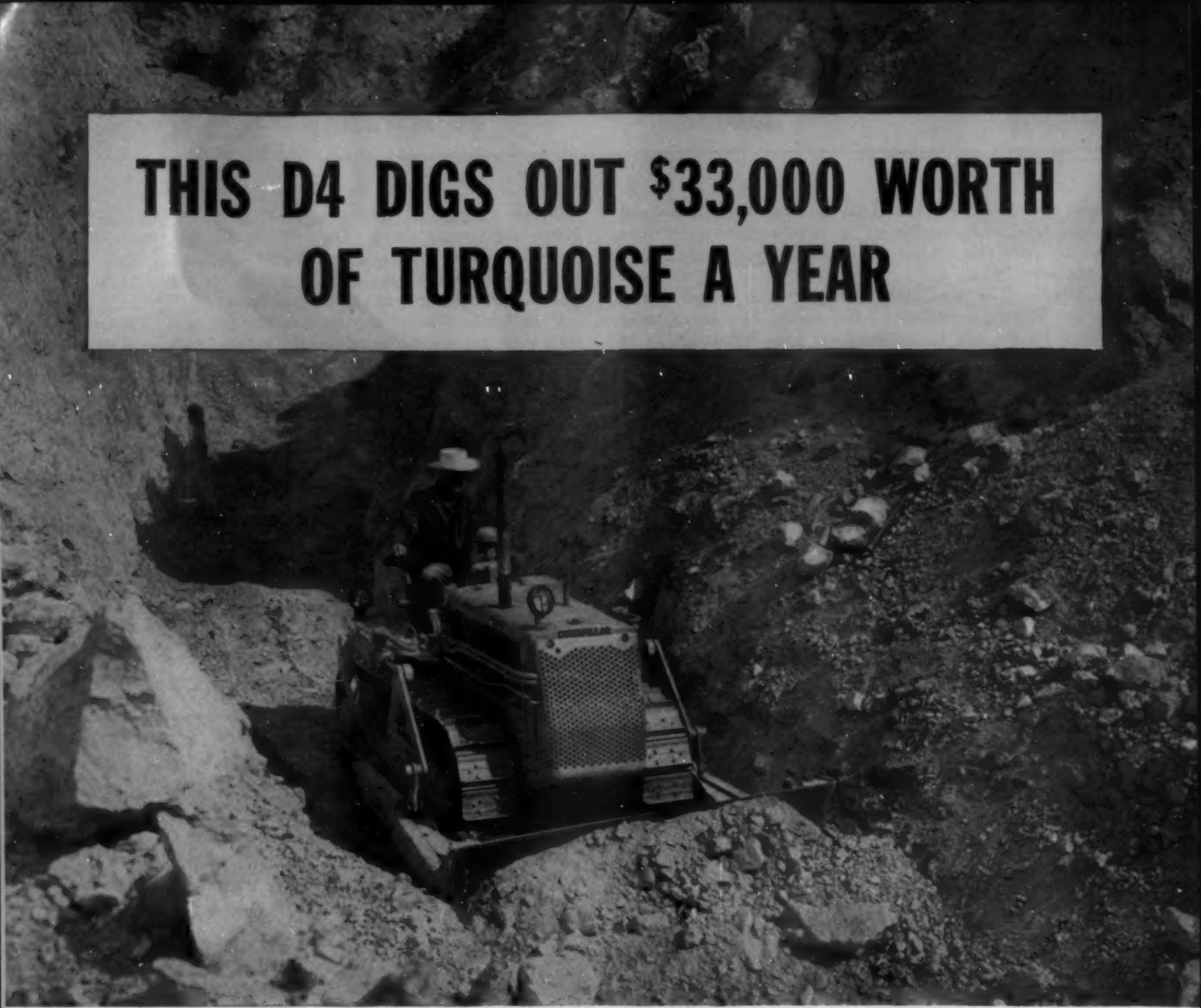
ANOTHER research tool has been unveiled—this time a jet of atomic vapor said to be twice as hot as the surface of the sun. The University of Chicago developed the new device at their Midway Laboratories. The jet is obtained by a water-stabilized electric arc which squeezes the heat of a carbon arc into concentrated form. This concentration has produced temperatures as high as 25,600°F, compared to 11,250°F at the surface of the sun. So far it has been sustained in operation for as long as three minutes.

T. R. Hogness, director of the laboratories, explains that the device was developed "to study the behavior of materials under extremely high temperatures. Valuable scientific experiments are being conducted which are providing data impossible to obtain before this development. Although the primary motivation was to investigate the behavior of hypersonic missiles, many new basic research studies in chemistry and physics can now be undertaken." Heat of the arc allows close studies of what happens to metals at the temperatures produced by meteor-like speeds, thus lessening the need for hypersonic wind tunnels.

The arc's heat is intensified by a spinning cylinder of water surrounding it. It is explained that this wall of water confines the arc and concentrates its energy. Some of the water vaporizes, feeding molecules of oxygen and hydrogen to a stream of vapor, *plasma*, that jets through a ring-shaped opening of one graphite electrode. It is this superheated jet of plasma into which metals and other materials are plunged for testing.

Plans call for replacing the water with liquid air, nitrogen, and helium to simulate conditions that would be encountered at different levels of the atmosphere.

Eight thousand kw was needed to produce the highest temperature attained so far—nearly twice the power used by the entire campus. Greater concentration of this power, say the arc's designers, can produce temperatures near 50,000°F.



You're looking at some of the richest rock in Colorado. Here, northwest of Villa Grove, gem turquoise comes out in chunks valued from $30 to $150 a pound. To get it, the Villa Grove Turquoise Lode Co. uses this husky Caterpillar D4 Tractor with No. 4A 'Dozer.

On a good day this D4 'dozes a hundred tons of rock and overburden and moves them a distance of some 200 feet. Last year it carved out over $33,000 worth of turquoise.

Owner M. C. Winfield chose the CAT* D4 Tractor for this job because he liked its power. There's 50 drawbar HP in this machine, with a maximum drawbar pull of 10,700 pounds. There's sturdy quality built into every inch, from the long-life track pins and heavy-duty track rollers all the way into the rugged, dependable transmission. And Caterpillar's famed oil clutch, job-proven by thousands of hours of hard-working service, is available now on the D4.

Other important features include an exclusive all-weather starting engine (it gets mighty cold up in this Colorado country!) and a fuel injection system that squeezes power from every drop of low-cost, non-premium fuel.

Your Caterpillar Dealer will be happy to demonstrate the D4—or any other of his big yellow machines—right out on your job. He's the man to call for expert service, too, and for replacement parts you can trust.

Caterpillar Tractor Co., Peoria, Illinois, U. S. A.

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**NAME THE DATE...
YOUR DEALER
WILL DEMONSTRATE**

Responsibility

by Herbert Hoover, Jr.

Acceptance speech by Mr. Hoover following presentation of the Hoover Medal (joint award sponsored by the Four Founder Engineering Societies: AIME, ASCE, ASME, AIEE) at the annual banquet held during the AIME Annual Meeting in New Orleans on Wednesday, Feb. 27, 1957.

IT is one of the greatest honors that can come to any engineer to accept this award from the Four Founding Societies. For me, in this instance, it is doubly so.

First, there are few honors that can come to a professional man for which he is more deeply grateful than one that comes from his own fellows in the profession. And, secondly, added to this gratitude on my part is the appreciation that this award was named in honor of my father.

It has been the purpose of this award to recognize public service among engineers. To that principle I most heartily subscribe, for engineers have a particular opportunity and responsibility to tackle many of our present day problems. That they are doing so in increasing numbers is a logical outgrowth of their training, their experience, and of the traditions of their profession.

Many of the complexities that we face today, whether they are of community, national, or international character, have their origins in the very same situations that engineers are dealing with on a day to day basis.

As civilization moves forward, the demand for tangible things becomes ever more insatiable. The worldwide desire for a better standard of living, in the physical sense, is increasingly an engineering job—the job of translating our expanding knowledge of science into practicable goods and services. This technical area has, by popular conception, always been among the primary provinces of the engineer. What is not so generally realized, by the public at large, is that the engineer is usually just as much at home in dealing with an extraordinary variety of nontechnical problems.

Today, no engineer can do his job, particularly if he has management responsibilities, unless he is thoroughly conscious of the social, political, and economic factors that are at work around him. He takes them into account and deals with them just as seriously as he does with the physical problems of molecules, mathematics, or machinery. And he must be on equally as firm ground with respect to both theory and practice in working with these intangible forces as he is when handling the more tangible ones.

In fact, whether at home or abroad, many engineers gain a wider background of direct experience in dealing with governmental and social problems than is, perhaps, afforded to any other group.

Their work, whether in a professional or managerial capacity, brings them into frequent relations with many executive agencies and legislative bodies. In the process, they have explored the workings of much governmental machinery.

They have come to know at first hand something of the aspirations and ideals of people, as well as of the conditions and the productivity of their employment.

Most engineers have learned, too, that the laws of economics and finance are just as inexorable as the laws of nature and that theirs cannot be a world of wandering decimal places!

Out of these, and a myriad of other experiences, they have developed a thoroughly realistic and practical approach to idealism.

There are probably other reasons, besides training and experience, why engineers find themselves in public service. One of them, perhaps above all others, is the sense of responsibility that stems from the traditions of their profession.

As we look into the future, certainly, engineers will be faced with more responsibilities than ever before, both inside and outside their profession. The younger men, in particular, who are just beginning their careers, have an ever widening range of opportunities. To them, I would urge that they gain the broadest possible grounding in the fundamentals of the physical sciences and engineering and that they do the same in the social sciences and economics. On the technical side, the problems of tomorrow will not be confined to any one narrow area, for all of the fields of science and engineering are becoming constantly more interrelated.

Later, as these young men move forward in their profession, and especially if they assume management responsibility, they will find that the human, civic, and economic problems will become fully as important as the technical ones. It is here that a breadth of knowledge and a thorough grounding in fundamentals is as important as it is to have a sound technical foundation.

To these younger men, let me say one further brief word. They are entering one of the most constructive and honorable of the professions. They will have the satisfaction of working in a field which has almost limitless opportunities to contribute toward the betterment of mankind.

They are also entering a profession which, for generations, has demanded those high standards of honesty and integrity that we are proud to recognize among the foundations of our American way of life; for our engineering heritage places frank emphasis on moral and spiritual values and upon dedication to public service.

(Continued from page 505)

Driving the 8-mile tunnel presented one of the most difficult features of the project since it pierced various fault zones where badly fractured and broken rock and ground waters were encountered. This required the lining of portions of the tunnel with concrete. To improve hydraulics and facilitate cleaning, the tunnel floor has also been paved with concrete. During the height of construction the tunnel was worked from six faces.

The penstock emerging from the main tunnel at Yaupi Alto has an outside diameter of about 7 ft. Penetrating into the tunnel outlet some 300 ft, the penstock pitches down the mountainside at an average angle of about 25° to the powerhouse 1500 ft below.

Landslides were a constant problem in the construction of access and service roads. In several instances portions of the road had to be carved out of cliffs of solid rock, with workman lowered to the site by ropes.

R. P. Koenig, Cerro de Pasco president, pointed out that "Adequate power will now be available for the profitable production of slab zinc from all the low grade zinc concentrates currently being produced . . . Heretofore, substantially all such concentrates were stockpiled during periods when the market price for zinc was relatively low. This was done as it was uneconomic to sell them for processing outside of Peru because of the high ocean transportation and treatment charges per unit of recoverable metal.

"Located on a different watershed than the four other hydroelectric plants which are tied into Cerro de Pasco's integrated power grid, the Paucartambo plant doubles the firm power generating capacity of the corporation's operating subsidiary in Peru."

Tunnel of 13-ft average diam diverts water from headworks to powerhouse over 8 miles of Andean foothills. Concrete fully lines 61 pct of total length. Entire floor is concrete-paved.

Four Companies Study Missouri Iron Ore

St. Joseph Lead Co. and Bethlehem Steel Corp. are studying the prospects for development of a newly discovered iron deposit in east central Missouri. Following this development—announced by St. Joseph Lead—Granite City Steel Co. and American Zinc, Lead, & Smelting Co. announced that they had formed a joint venture for exploring the state for iron orebodies.

St. Joseph Lead said that one iron deposit, of three discovered about 40 miles from Bonne Terre as a result of an airborne magnetometer survey and exploration, has been drilled sufficiently to indicate probable large tonnage of commercial grade iron ore. The deposit, known as the Pea Ridge, lies at a depth of between 1400 and 3000 ft. "In February 1957, Bethlehem Steel approached us with a proposal to form a joint 50/50 company to exploit the Pea Ridge deposit," St. Joe reports. "Under the suggested arrangement, St. Joe would take the major responsibility of operating the mine and Bethlehem would supply the major financing, their knowledge of iron ore beneficiation, and a market for the product. We are actively studying this interesting proposal on the basis of an annual output of 2 million tons." It added that a probable five years would be needed before the property reached the production stage.

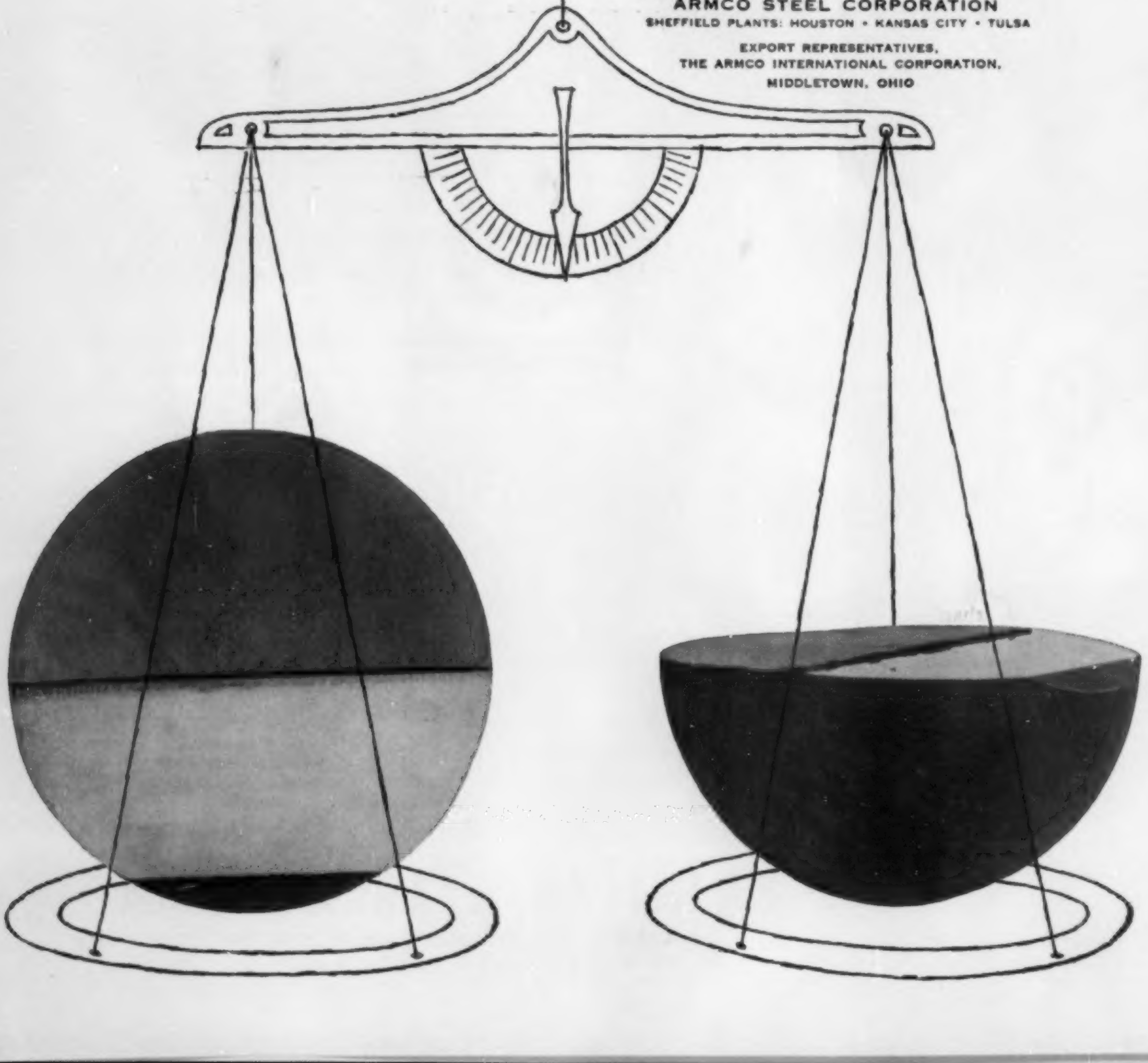
The agreement by Granite City Steel and American Zinc, Lead, & Smelting contemplates development of mining properties for the use of both companies in the event commercial ore discoveries are made. Exploration and development expenses will be shared equally by the two companies. Operation of any mining properties developed will be handled by American Zinc.

AEC Contract For New York U_3O_8 Pilot Plant

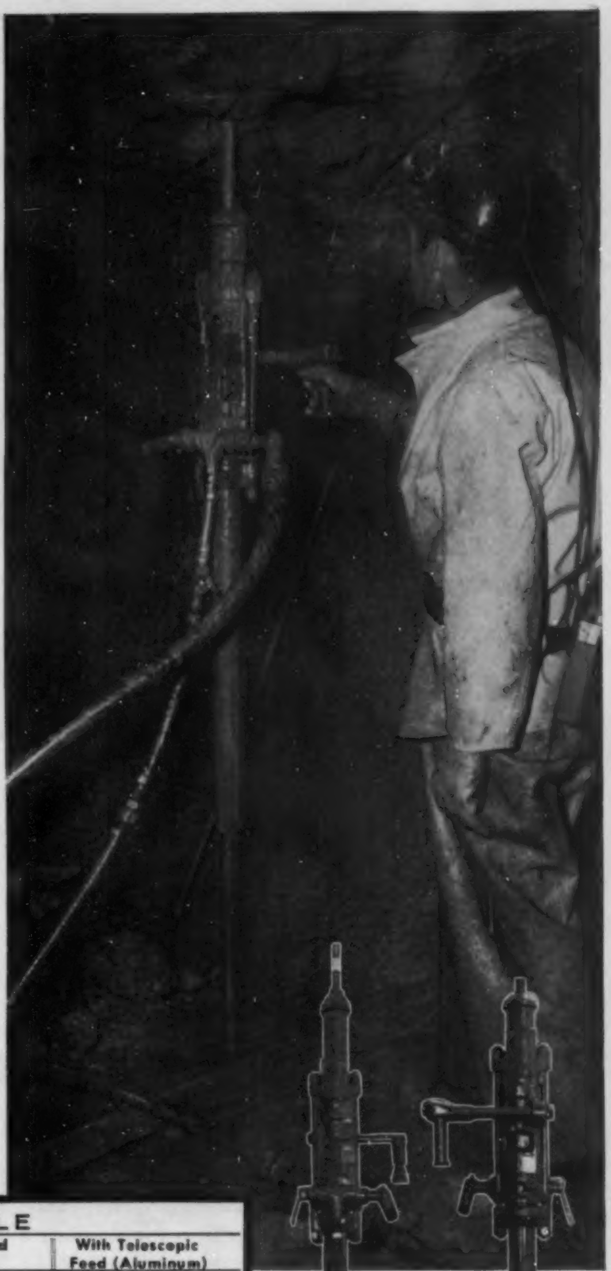
In a one-year contract signed with Ramapo Uranium Corp. of New York, the Atomic Energy Commission has agreed to purchase, at \$8 per lb, U_3O_8 in uranium concentrates produced in a pilot plant at Warwick, N. Y. Under the contract, a maximum of 50,000 lb may be purchased.

The pilot plant will process uraniferous ores of the Warwick area owned or controlled by the corporation. Uranium ore may be purchased for treatment from other properties in the area if they should produce it.

In development operations of this type for which production costs cannot be determined in advance, the AEC purchases small quantities at \$8 per lb of U_3O_8—the price set for concentrates after Apr. 1, 1962.



NEW!



GARDNER-DENVER R68

New drilling speed
New ease of operation

Here's a new stoper with added automatic features that increase drilling speed and handling ease. The new R68 has all of the rugged strength, operational efficiency and top manufacturing qualities of all other widely used G-D stopers—another example of Gardner-Denver engineering foresight.

New R68 features:

1. Gardner-Denver automatic water control—operating on the "water on—air on; air off—water off" cycle.
2. Push-button or rotary type feed controls.
3. Equipped with automatic blowing through chuck end—keeps mud and abrasive cuttings out of drill.
4. Is available with collared or tappet chuck. Your choice of direct or telescopic feed.

Write for complete details.

SPECIFICATION TABLE

Model R68	With Direct Feed (Steel)				With Direct Feed (Aluminum)				With Telescopic Feed (Aluminum)		
Steel Change	18"	24"	30"	36"	18"	24"	30"	36"	18"	24"	36"
Weight: (With Tappet Chuck) lb.	94	97	100	103	80¼	82¼	84¼	86⅛	90	91	94
Weight: (With Collared Chuck) lb.	89¾	92¾	95¾	98¾	76	78	80	82	85¾	86¾	89¾
	Steel Sizes: Hex or Q.O.—⅞" or 1"										

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CERTIFIED POWER

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CATERPILLAR TRACTOR CO.

ENGINE POWER CERTIFICATION

This is to certify that the Diesel Engine herein described has been engineered, manufactured and tested in accordance with rigid Caterpillar Standards. The materials and workmanship incorporated into this engine give it the inherent capacity for satisfactory performance when applied in accordance with the power ratings established and recommended by this company. The MAXIMUM OUTPUT capacity of this standard production engine is 200 *H.P. @* 2000 *R.P.M. equipped with: air cleaner, water pump, lubricating oil pump, fuel pump, and standard intake and exhaust manifolds.*

I certify that B. L. Henson Supervisor of Diesel Engine Test, Caterpillar Tractor Co., ... Certification and I affix my ... 19 57

B. L. Henson
Supervisor Diesel Engine Test
Caterpillar Tractor Co.
Peoria, Illinois

... /58

was manufactured and

Caterpillar Model D326 Industrial

shipped as follows: Engine Serial No. 39B1018 Shipping Date February 11, 1957

Power Setting 152 H.P. @ 1600 R.P.M. Intermittent Power Rating

Radiator & Fan
Ether Starting Aid
32V Charging Generator
Governor Control
Tachometer Drive
Muffler
Heater Connections
Remote Shut-off

POWER RATINGS

MAXIMUM OUTPUT is the horsepower capacity of the engine; a measure of the maximum power, ± 5%, that can be developed for five minutes without drop in speed.

INTERMITTENT HORSEPOWER is a rating for use in variable load applications such as excavators, hoists, and standby power units, where the duration of sustained full power output is one hour or less, with the average output not over 80% of Intermittent Horsepower.

RATED HORSEPOWER is a rating for use in applications such as planing mills, hammer mills, and rock crushers where the duration of sustained full power output is 12 hours or less.

CONTINUOUS HORSEPOWER is a rating for use in applications such as work-boats and pumps where the duration of sustained full power output is 24 hours per day, day in—day out.

Horsepower figures are established in accordance with rigid Caterpillar standards. All ratings, corrected to sea level barometric pressure (29.92 in. Hg.) and standard temperature (60°F), apply to a production engine including air cleaner, water pump, lubricating oil pump, fuel pump and standard intake and exhaust manifolds. The above ratings are based on British and American BHP.

Printed in U.S.A.

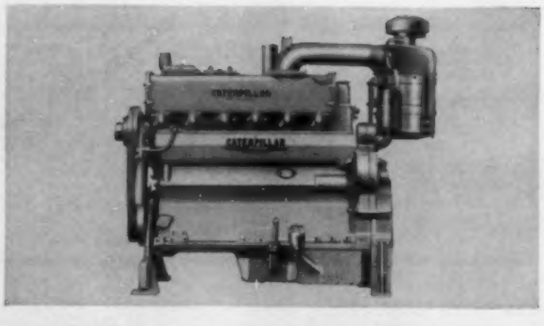
FORM NO. 515-22253

In a quarter century of diesel leadership Caterpillar Engines have achieved a reputation for *honestly rated power*. Owners have found that they can depend on a Cat Diesel to deliver the power promised.

Now, to back this reputation, Caterpillar becomes the *first* manufacturer to issue a certificate showing the horsepower capabilities of the engine. This certificate is signed by Caterpillar Tractor Co. and certified by a notary public.

You have a right to demand *certified power* when you invest in an engine. You get it when you buy from your Caterpillar Dealer. Let him show you the certified power plant that fits your needs.

Caterpillar Tractor Co., Peoria, Illinois, U. S. A.



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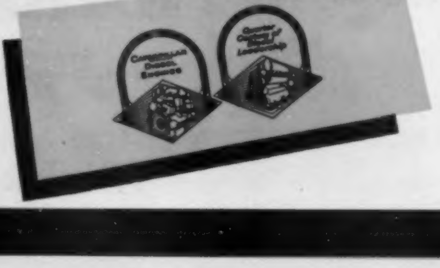


The Copperbelt of Northern Rhodesia

Based on a speech delivered by Sir Ronald L. Prain at a meeting of the New York Section of AIME, Feb. 7, 1957.

OUTLINE OF AFRICA SHOWING LOCATION OF RHODESIA AND THE COPPERBELT

THE COPPERBELT NORTHERN RHODESIA

WE must begin by defining what we mean by the Copperbelt. This term is generally used to denote that region of Northern Rhodesia in which the copper mines of that territory are situated. The first published use of the term *Copperbelt* we have been able to trace dates back to 1905. The *African World* of December of that year contained an article entitled "The Great Northern Copper Belts of Rhodesia." The next reference we have traced is in 1909 in an article in the Transactions of the Geological Society of South Africa. It began to be used generally in the late twenties and by 1929 was in common use to denote the region which today contains the existing large copper mines of Northern Rhodesia.

The first of three accompanying maps is a very simple outline map of Africa showing where Rhodesia is within Africa, and where the Copperbelt is within Rhodesia. The second is a larger scale map of the Copperbelt itself. It will be seen that within the present Copperbelt there are six producing mines. Two of these are new and four are relatively established, having started operations between the two world wars. The Copperbelt also includes a township called Ndola, which is not a mining town, but a railhead on the main line. This town has developed primarily as a result of the mining industry in the neighborhood. It describes itself as the Gateway to the Copperbelt and is shortly to become a refining center.

If we take this area and lay it on a map of Connecticut on the same scale, it would cover an area bounded approximately by Stamford, New Haven, and Hartford. To put it another way, the area is about two-thirds the length of Long Island and approximately the same width.

The region as a whole lies in the Western Province of Northern Rhodesia. Northern Rhodesia is one of the three territories making up the Federation of Rhodesia and Nyasaland, the other two being Southern Rhodesia and Nyasaland.

There is considerable prospecting being done outside the present Copperbelt and, should new mines be discovered within those prospecting areas, the definition of the Copperbelt will undoubtedly be extended to cover such new mines as well. In other words, the expression *Copperbelt* is at present a

SIR RONALD L. PRAIN, O.B.E., is chairman of Rhodesian Selection Trust Ltd.

OUTLINE MAP OF THE RHODESIAS

loose one and may well, as time goes on, become an expanding one.

The Copperbelt lies immediately to the south of the Rhodesia Congo border. The boundary between Rhodesia and the Congo at this point was ill-defined before the late 1920's. On the other side of the border lie the great copper mines of the Katanga Province of the Belgian Congo. The opening up of the Rhodesia Copperbelt made it essential that this border should be defined exactly, especially as one of the Belgian mines, the Kipushi mine, lies actually on the border. As a result of this necessity an Anglo-Belgian Mission completed an exact delimitation of the border in 1932. The border they established at this point follows the watershed between the Zambesi and the Congo rivers.

Within the Copperbelt exists the third largest copper-producing industry in the world. From its mines there now comes a copper production of about 500,000 tons a year. Within the industry there are employed approximately 7000 Europeans and 38,000 Africans who, with their families, constitute a population of at least 137,000 on the mines property. If we take into account the other people living in the Copperbelt who find employment as an indirect result of the copper mines, including all Government officials, personal servants, and those working on the railways, in the stores and industries, we estimate that there are perhaps 400,000 people living on the Copperbelt and owing their existence there in one way or another to the copper-mining industry.

In 1955 the copper industry accounted for 63 pct of the exports of the Rhodesian Federation and 94 pct of Northern Rhodesia's exports to destinations outside the Federation. In the financial year 1955/56 the industry provided about three-eighths of the total revenue of the Central African Federation.

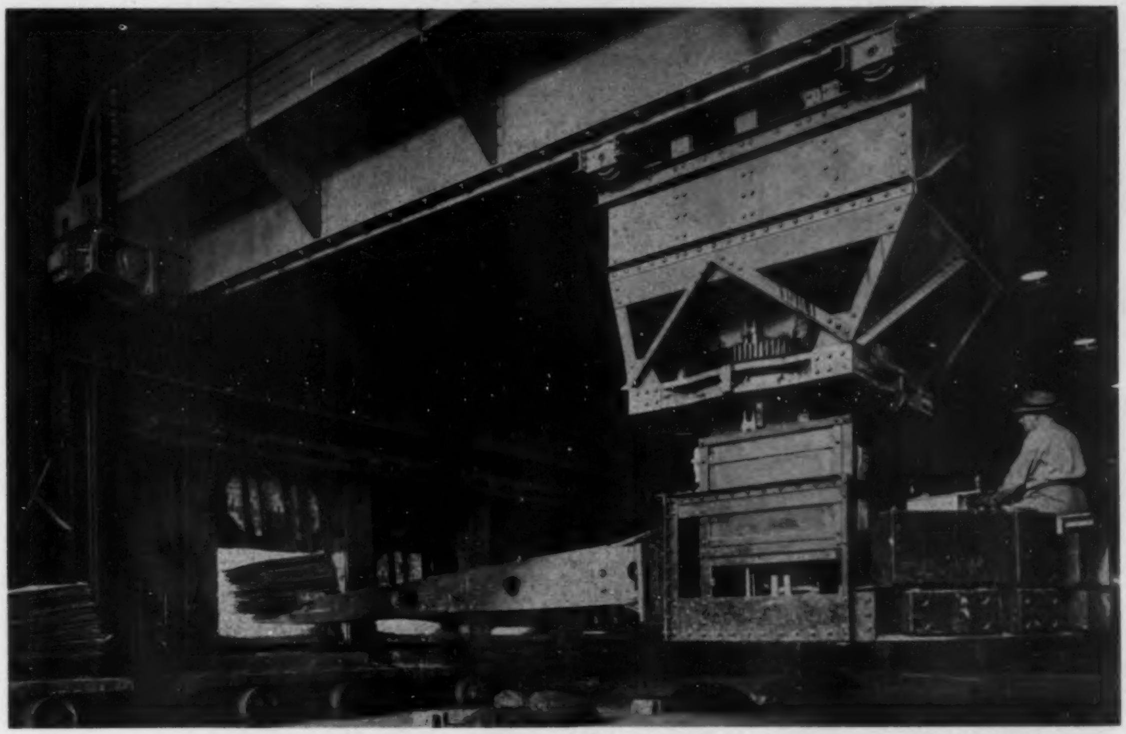
This is one of the largest integrated industries south of the Equator, and it is today the most valuable extractive industry in the British Colonial Empire, second only to rubber when valued by reference to its export value. The amount of development taking place in Northern Rhodesia, chiefly in the Copperbelt, in terms of gross capital formation (to use a statistician's term) is, according to the available evidence, at present greater per head of population than in any other British Colonial territory in Africa.

The commercial and strategic importance of the Copperbelt is matched only by the complexity of the problems this industry has to face, problems that arise partly from its remote location and partly from the inevitable and sudden impact of a highly complex modern industry set down among some of the most primitive people in the world, from which such a large proportion of its employes must be drawn. The situation brings with it social and economic problems on a scale difficult to match elsewhere. These problems will be described later.

Origin of the Copper Industry: The history of this industry is of comparatively recent origin. Copper had been worked for centuries in central Africa by the native peoples on a most primitive scale, stimulating a certain amount of prospecting in central Africa after this part of the world attracted public attention as a result of the travels of David Livingstone. The first prospecting by Europeans appears to have occurred towards the end of the last century, and it was in 1899 that George Grey discovered the Kansanshi mine and in 1902 that the outcrop of the Roan Antelope mine was discovered by a prospector named William Collier, who also in that year found the Bwana Mkubwa mine.

Even these discoveries, however, attracted little attention at the time owing to certain factors then considered unfavorable for the opening up of copper mines in this part of the world. There were at least four major factors. To begin with, there were enormous distances and transportation problems involved, and secondly there were health problems, among which the scourge of malaria appeared to be insuperable. Thirdly, at that time the United Kingdom had the whole world to buy copper from and had not yet experienced the dangers of a world war, nor the embarrassment of a dollar shortage. The fourth problem concerned the technical difficulties of treating the particular types of ores represented in the Kansanshi and Bwana Mkubwa mines.

Grade of Rhodesian Ore: Most of the problems, however, disappeared during the following 25 years. The railroad was extended from the Victoria Falls to the Belgian Congo to serve, first, the Broken Hill lead and zinc mines and, secondly, the Katanga copper mines. The pioneer work of Ross and Watson in the Malay Peninsula showed how malaria could be controlled. The growth of metallurgical and geological experience during the first quarter of the century also completely altered the outlook towards the Rhodesian occurrences. In the Katanga, oxide ores averaging as much as 15 pct copper were common, but the search for similar deposits on the Rhodesian side resulted in discovery of ores of much lower grade, with an average of perhaps 3 to 5 pct copper, also in the form of oxides. Pitting and shaft sinking down to water level gave discouraging results. What was not realized until later was that at moderate depths, but generally well below ground water level, these same lean Rhodesian oxide copper deposits turned to sulfides still running from 3 to 5 pct copper. This realization occurred at about the time that metallurgical science was discovering the flotation method of concentration. The combination



A charger places a load of cathodes into a wire bar furnace at the Nkana refinery. Nkana is the main treatment center for the Anglo American Corp. mines in Northern Rhodesia.

of new geological and metallurgical knowledge created immense interest in the Rhodesian deposits, which suddenly assumed an economic value never previously attributed to them.

During this quarter century, furthermore, the United Kingdom had learned the lessons of a world war and was determined, if possible, to acquire its own soures of copper for the future.

The combination of all these factors led to renewed interest in this part of the world, and it was in the 1920's that exploration on a really considerable scale began. Tribute should be paid at this point to what is perhaps the most important single step leading to the opening of the Copperbelt—the decision made in 1923 by the British South Africa Co., which owned and still owns the mineral rights of Northern Rhodesia, to grant sole prospecting rights over large areas of the territory to strong financial companies. The 1920's were essentially the years of the concession companies such as the Rhodesian Congo Border Concession Ltd. and the Nkana Concession, and it was during that time that the mines of Mufulira and Nchanga were discovered.

Discovery of the Nkana Mine: The Nkana mine was discovered in 1910 by Moffat Thompson. The Kansanshi and the Bwana Mkubwa mines already mentioned produced copper before World War I. The Kansanshi mine suspended operations on the outbreak of war, while the Bwana Mkubwa mine, which started in January 1913, suspended operations in September 1914. It resumed operations in 1916 and continued until the end of March 1918. During those two periods of activity the mill treated about 69,000 tons of ore assaying about 10 pct copper. The concentrates were sent partly to the Falcon Smelter in Southern Rhodesia and, during the war, a certain tonnage was shipped to England. This mine again produced some quantities in the late 1920's but was shut down about 1930. These productions, however, were in a way experimental and of no importance in the world's copper picture. At the present time the Bwana Mkubwa mine potential is again under investigation, and Kansanshi is due to produce a small tonnage while exploration of its potential also continues. The important era of Rhodesian copper production began with the decision to develop the four orebodies of Roan Antelope, Nkana, Mufulira and Nchanga. The result was immense financial activity, mostly in London, but also in New York and Johannesburg, and the formation of large companies to operate these mines. Production on a large scale began in 1931 and has continued unbroken on an increasing scale.

Effect of Sterling Devaluation: The next major development for the Copperbelt was in 1949 with the devaluation of sterling and the consequent increase in the sterling price of copper. This led to further interest in the copper mines and, coupled with an enlightened tax code introduced in 1951, it led to the beginning of two new mines, to be described in due course.

Organizationally, the mines of the Copperbelt fall into two groups, one predominantly controlled by British and American interests, and the other predominantly by South African interests. These two groups between them control all the companies concerned directly with copper mining and, in addition, more than a dozen subsidiary companies which serve the main mines. The following brief résumé deals with each of these mines in the order in which they came into production.

Formation of Roan Antelope Co.: Roan Antelope, already mentioned as being discovered in 1902, was formed into a company in 1927 and started production in 1931. This mine is situated next to a town called Luanshya, shown on the map down towards the southwest corner of the Copperbelt. This mine is today hoisting and milling between 5 and 6 million tons of ore each year and on this basis can claim to be the largest underground copper mine in the British Empire. It is large by any standard, having a peculiar shape to its orebody, the strike of which extends for about 10 miles on the surface. To work this orebody 24 shafts have been sunk from the surface and no less than 1000 miles of underground workings have been driven. The ore is crushed, floated, and then smelted to produce a blister copper that is shipped to the markets of the world, and the actual copper production runs between 95,000 and 100,000 tons a year. There are about 1620 European employes at Roan and 9100 African employes. The African employes live in an African township of more than 1000 acres—probably the largest African mine township on the subcontinent.

Thirty-four miles by road to the north of Roan Antelope is the Nkana mine, discovered in 1910 and now owned and operated by Rhokana Corp., successor of the Rhodesian Congo Border Concession Ltd., which was formed in 1923. There are actually two mines worked jointly, Nkana and Mindola. They began production in 1931 and today produce about 95,000 tons of copper a year.

Nkana Smelter: In addition to being a mining center, Nkana is a concentration of smelting and refining facilities. When the extensions to the present smelter are completed this will be the second largest in the world. Some of the plants at Nkana are treating copper from other mines. There are more than 1800 employes at Nkana and about 10,400 African employes.

Nkana is also about the geographical center of the Copperbelt. For this reason the adjoining township of Kitwe has attracted to itself a considerable number of centralized business activities, in addition to secondary industries and stores that are established there. It contains the headquarters of the Chamber of Mines and the various mining unions, as a result of which Nkana and Kitwe together form the biggest population center on the Copperbelt. This dual town is growing at a phenomenal rate and is easily the largest town in Northern Rhodesia.

Mufulira Mine: Twenty-six miles northeast of Kitwe is the Mufulira mine, which was discovered in 1923 and began production in 1933. Mufulira is capable today of producing about 112,000 tons of copper a year. Last year it was announced that it would increase production by about 50 pct, which would give it an output of about 168,000 tons a year. This would make it the third largest underground copper mine in the world. It has large ore reserves and its mining operations are conceived and carried out on a large scale. It is also the wettest mine on the Copperbelt—in fact, one of the wettest in the world. The amount of water pumped out of it daily is about ten times the amount of copper ore.

Nchanga, Chibuluma, and Bancroft Mines: Thirty-three miles north of Kitwe is the Nchanga mine, which was discovered in 1923 and came into production in 1939. The grade of ore at Nchanga is higher than that at the other mines, and although it does not mine and mill the highest tonnage of ore, the result in terms of copper is the highest on the Copperbelt, running today at about 123,000 tons per annum. This mine has huge reserves, and it will start an open pit operation in the near future which will even out the grade variations in the various parts of the mine.

The Chibuluma mine about seven miles west of Kitwe was brought into production early in 1956. This is a relatively small but high grade copper/-cobalt mine that is producing at the rate of 20,000 tons of copper a year. Cobalt concentrate will be smelted at a plant under construction at Ndola.

The Bancroft mine, about 15 miles north of Nchanga, started production only last month. Initially it will produce at the rate of 48,000 tons of copper a year and eventually, in 1959, 96,000 tons a year.

There are at least two undeveloped orebodies, the Chambishi and Baluba. Last year it was announced that, subject to the necessary finance being found, the Chambishi mine would be opened up as soon as possible. The mine has published ore reserves of 35 million tons of 3.37 pct copper, and it is expected that it might come into production about 1960 at a rate initially about the same as Chibuluma's. Baluba has published ore reserves of 70 million tons of mixed copper-cobalt ore running 2.68 pct copper and 0.18 pct cobalt.

By U. S. standards Copperbelt grades appear to be high. In the six producing mines the average grade in the various orebodies ranges from 2.64 to 7 pct, with an overall average of about 3.59 pct sulfide copper. It should be made clear that this is the block grade and that waste dilution will result, of course, in a somewhat lower milling grade. The total published ore reserves of the six producing mines and the two undeveloped mines are given as just over 700 million tons, capable of yielding at least 18 million tons of copper. This represents about 25 pct of the world's published ore reserves in terms of recoverable copper.

It may be of interest that the average Copperbelt reserve grade of 3.59 pct is just about double what we calculate to be the average ore reserve grade of all the published reserves in the free world. A recent study we made on this point appeared to indicate published reserves of 4,878 million tons of ore at a grade of 1.79 pct copper, containing a gross copper content of about 87 million tons. This is calculated to represent a recoverable content of about 72 million tons of copper, or 24 years' reserves at the 1955 consumption rate for new copper in the free world. This would fall to 18 years' reserves on the basis of 4 million tons a year consumption, which some people estimate may be the rate in 5 years.

On the other hand, we all know very well that published ore reserves are far from being the full picture. A recent International Geological Congress estimated that the world reserves, including inferred ore, might be about 190 million tons of copper metal. It must therefore be emphasized that the figures presented here are based on the published proved reserves and, even if these tonnage figures can be discounted to some extent, there is a definite conclusion to be drawn from the grade figures just given, namely, world average reserve grade, 1.79 pct, and Copperbelt average reserve grade, 3.59 pct. In both cases these are block grades and not milling grades, and it can be said that on a milling basis the Copperbelt average grade would have to be brought down more than the world average grade.

Some of these mines produce, or will produce, metals other than copper. For many years the Rhokana Corp. has been producing cobalt, and at present its rate of production runs about 2.4 million lb per annum, which represents about 10 pct of the world production. Chibuluma will also produce cobalt at a rate which has been announced at 1 million lb per annum, and cobalt is known to exist in, for instance, the Baluba mine. All these mines produce small quantities of gold and silver as a byproduct of electrolytic refining, but they are not important producers of these metals in any sense. Rhokana will produce some uranium.

Among copper producing countries the U. S. comes first with an annual production of more than 1 million tons. In 1953 and 1954 Northern Rhodesia held second place, which is now occupied by Chile. As mentioned earlier, if the Katanga is taken as the same geological field as the Rhodesian field, this district would today be very easily the second, and one day perhaps the first copper producing field of the world.

Of the dozen or more subsidiary companies that exist to render services to the producing companies, perhaps the most important are those dealing with provision of power supplies and refining facilities.

Rhodesian Power Supply: The Rhodesia Congo Border Power Corp. exists for the purpose of purchasing the power produced at the four thermal power stations at the mines and redistributing this power throughout the Copperbelt. In addition, the transmission of power from a hydroelectric scheme on the Lualaba River in the Belgian Congo to the Corporation's central switching station at Kitwe started during 1956. This power is the result of agreements entered into between the companies and the Union Miniere du Haut Katanga.

There have been many reports of the recurrent power shortages on the Copperbelt since the end of World War II. Today, at last, there is sufficient power. A brief history of the post-war years in this respect may be of interest.

The natural fuel for these mines is coal supplied by the Wankie Colliery in Southern Rhodesia. The Wankie Colliery has always been a key factor in enabling this industry to start up in the first place, and to carry on in the second. There is no other major source of coal within the Federation and for many years no real problem existed, as the capacity of the Wankie Colliery to supply coal to the Copperbelt was not in any doubt. With the great expansion of this industry in recent years, and with the equal expansion of European population and of secondary industries throughout the Federation, the Wankie Colliery was hard put to it to supply enough coal for the copper industry, the railroads, and other requirements of the Federation. This particular aspect of the problem was solved some two or three years ago, for since then the colliery has been able to produce coal in excess of the requirements of the Federation. The problem since then has been principally one of transporting the coal from the colliery to the various users within the Federation. The Rhodesia Railways system has been found unable to carry the full requirements of the Federation, and until this railway can be brought up to its contemplated carrying capacity, the consumers of the Federation have been rationed. In this way the Copperbelt, with a requirement until recently of 90,000 tons of coal per month, has been unable to receive more than about 70,000 tons, and the difference has been made up for many years now by resorting to the expediency of burning wood. Fortunately, there has been no shortage of wood, and from 1946 until very recently the copper companies conducted a large-scale campaign of cutting wood in the local forests and transporting it to power plants of the Copperbelt.

In addition, the Copperbelt burnt some oil and imported high-priced coal from the U. S. These expensive but necessary expedients have now been eliminated entirely by the supply of power from the hydroelectric scheme on the Lualaba River in the Congo. The last of the three maps accompanying this article shows how this power is carried from the Le Marinel Station on Lualaba to the central switching station at Kitwe.

The present installed capacity of the thermal power stations on the Copperbelt is about 197 megawatts, with a continuous effective capacity of 170 megawatts. This requirement is increasing all the time with the advent of new mines and of greater loads by the old mines—by 1959 requirements for the Copperbelt will be about 240 megawatts and by 1961 about 270 megawatts. It is considered that the combined capacity of the thermal plants has now reached its practical limit, and all plans for additional power from 1960 on are based on receiving it from the great hydroelectric scheme now being constructed at the Kariba Gorge on the Zambesi River. This also is indicated on the map.

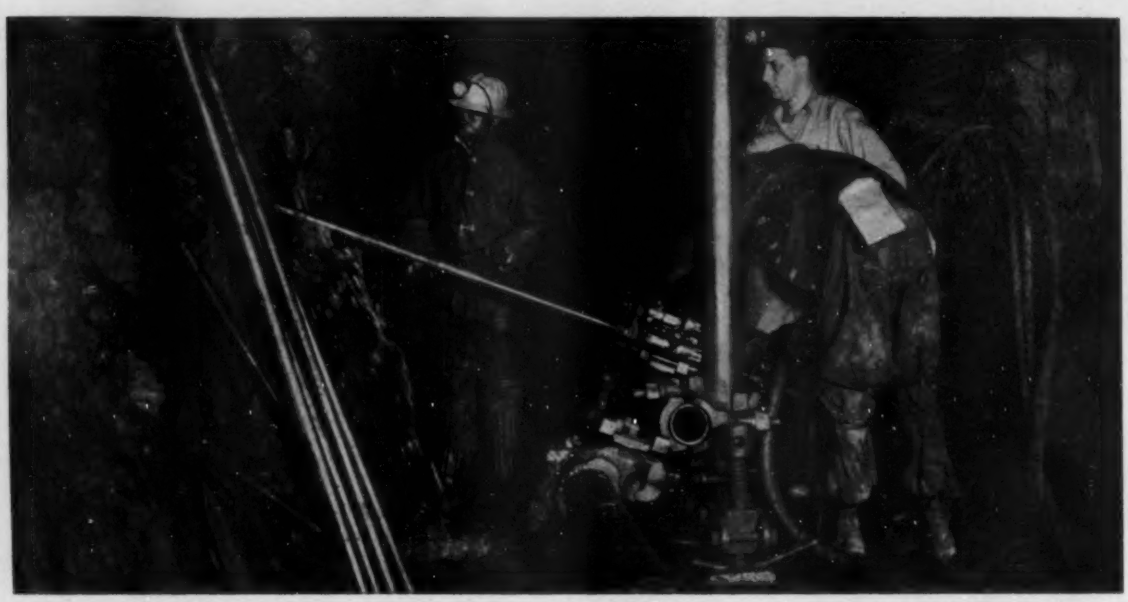
The Kariba Hydro-Electric Scheme is estimated to cost about $225 million for the first stage, which will give it a capacity of 500 megawatts. The finance for this stage is being found to a large extent by the World Bank and by the Rhodesian Copper companies themselves. The planning of this scheme provides for later developments at an additional cost of about $100 million, which would then give it a capacity of 1200 megawatts. This scheme will, of course, provide power for the Rhodesias generally and not only for the Copperbelt, but there is no question that the decision to proceed with this new source of power was taken primarily on account of the Copperbelt power position.

The Kariba Dam will create a lake on the Zambesi River which will be 175 miles long with a maximum width of 20 miles and an average width of 12 miles. The area will be 2000 square miles and the volume 130 million acre-ft. This will be the largest man-made lake in the world, about four and a half times the size of the lake back of the Hoover Dam.

When the Copperbelt is linked to the Kariba Scheme, the total system that will be controlled by the Rhodesia Congo Border Power Corp. will extend from the Lualaba in the north to the Zambesi in the south, a total distance of nearly 800 miles, making this the longest integrated power system in the world.

Refining of copper is done by three refineries. One of these three belongs to the Mufulira Co. and exists for the purpose of treating only the Mufulira output. The other two are respectively owned by the Rhodesia Copper Refineries Ltd. and the Ndola Copper Refineries Ltd., both of which exist to treat the output of more than one mine.

The subsidiary companies include the Northern Rhodesia Chamber of Mines, which is the employers' organization, and companies supplying timber, labor, air services and technical services, as well as an estate company, trustee companies, and prospecting organizations.



Diamond drill setup at Nchanga copper mines. The grade of ore at Nchanga is higher than that of the other mines in the Copperbelt.

Several of the latter companies, covering very substantial areas of Northern Rhodesia, are owned by the main producing groups. Map No. 3, which shows the power lines, also indicates areas covered by the prospecting companies connected with these two groups. Over these areas prospecting is now taking place on a scale comparable to that which occurred in the 1920's. It is too early to say whether these prospecting campaigns will discover new mines of substantial size. The possibilities, we believe, amply justify the effort, as some of the areas cover the same geological series that constitute the Copperbelt.

The figures quoted earlier as to the relative importance of the copper industry within Northern Rhodesia and within the Federation illustrate the obvious fact that the copper industry is virtually a mono-economy, at any rate as far as Northern Rhodesia is concerned. Even taken within the context of the Federation the copper industry is overwhelmingly the largest within the Federation. It may be compared to the mono-economy of Chile with its similar copper industry, or with the oil industries constituting mono-economies in Iran and Venezuela.

Standard of Living: The earlier hazards of malaria and other tropical diseases are now largely a matter of historical record. With the modern methods of eliminating these hazards, the Copperbelt, and in fact the whole of the Rhodesias, finds itself situated in a climate which compares well with any other in the world. The companies have created amenities and facilities for both their European and African employes which it would be hard to equal in the mining industry. Africans who only a few years ago were living in primitive conditions in the bush now live in houses with electric light and water-borne sewage and enjoy medical facilities comparable to the services available to the majority of people in Europe. Their diet contains a calorific value higher than that available to nine-tenths of the world's population.

The scale of pay and remuneration for both European and African employes is comparable to that found anywhere else in Africa. This refers, of course, to two different scales of remuneration, one scale for the European, which compares favorably with that of Europeans anywhere else in the mining industry in Africa, and the other for Africans, which compares more than favorably with that for Africans anywhere else within the Federation.

European-African Social Problems: There are, of course, social problems created by the existence of two civilizations living and working side by side. Highly skilled Europeans work in a complex modern industry established in the middle of a primitive community which must supply the common labor. The difference between the living standards and the remuneration of these two communities must create, as time goes on, an ever increasing problem. It is clear that Europeans must enjoy relatively high standards if they are to be attracted in the first place. It is equally clear that the indigenous community is not yet ready to enjoy such standards.

The European community in the Copperbelt was understandably concerned with the protection of its standards in the face of potential competition from indigenous workers, and increasingly anxious to safeguard its position. In fact, this position in the years after the war was protected by agreements entered into between the European Union and the companies during the war, under which the jobs then belonging to European employes could not be given to Africans.

On the other hand, the African workers over the years have increasingly sought financial advancement, as well as the opportunity to take better and more skilled jobs.

During the years after the war this problem appeared to be insoluble, and much thought and discussion were devoted to it. The Northern Rhodesian Government appointed several commissions to inquire into the position and report on it. From time to time the companies also attempted to come to some agreement that would provide reasonable safeguards for the European employes and at the same time satisfy the legitimate aspirations of the

African workers. No real progress, however, was made until a year or two ago.

In 1953, when the British Government ceased the bulk purchase of Rhodesian copper, the companies initiated discussions with the European Union. These discussions continued under difficult circumstances from 1953 to September 1955, when an agreement was reached between the Union and the companies under which, for the first time, the principle of a color bar on the Rhodesian Copperbelt was broken. As a result of this agreement, it is now possible for an African to have any job at equal pay with the European.

The agreement provides for a certain number of jobs previously held by Europeans to be handed over to Africans and, furthermore, for a complete analysis to be made of all remaining jobs on the Copperbelt with a view to seeing whether any of these can be fragmented or broken down into processes which would enable the African to learn these skills gradually and at the same time be advancing up the ladder of advancement to the time when he can do a full European job at full European pay.*

* Since delivery of this address we have been advised by the author that it would be more strictly correct if this passage were to read as follows:
The (African Advancement) agreement provides for a certain number of jobs previously held by Europeans to be handed over to Africans and furthermore for a complete analysis to be made of all remaining jobs on the Copperbelt. From such an analysis it should be possible to see whether any of these can be fragmented or broken down into processes which would enable the African to learn these skills gradually and at the same time be advancing up the ladder of advancement to the time when he can do a full European job at full European pay.

There appears now to be a real understanding on all sides of the important issues involved and a genuine willingness to reach agreement. It is no secret that solution of this problem is regarded by many people, both within and without the industry, as the most urgent matter facing the Copperbelt, and perhaps the Federation of the Rhodesias and Nyasaland, whose policy is based on partnership between the races.

The Copperbelt has become notorious for the impression it gives of having strikes constantly. In point of fact, there are more rumors than actual strikes. An analysis of time lost since the war at the major copper-producing centers would probably show that the Copperbelt is no worse than anywhere else. There have been two or three major strikes—a European strike in 1946 and African strikes in 1952 and 1955. There have also been sporadic strikes involving a few days at a time or one mine at a time. On the whole, however, the Copperbelt gets on with the job of producing copper. The strikes that have occurred have not represented actual racial trouble in the accepted sense of the word. The series of so-called *rolling* strikes occurring in 1956 were really a manifestation of disagreement between the African Union and the African Staff Association and therefore could not be called interracial in the usual sense of the word.

Outlook for the Industry: If we assume, and we must assume, that future relationships between European and African workers will be resolved, we shall then have the prospect of an industry growing from strength to strength, with the possibility that within the lifetime of some of us it may become, together with the Congo, the main producing field in the world. In many respects the position is almost ideal. Here we have communities living, by reference to their own standards, under conditions that would be hard to find elsewhere. It has many favorable technical factors, such as the grade of the ores and the continuity and long life of the mines, which enable all planning to be on a semi-permanent basis. Yet the history of the nonferrous metal world is that the industry will experience years of slump and years of prosperity. It is so long since this industry experienced years of slump that few in the industry have any recollection of it. Consequently, there is perhaps some absence of cost-consciousness in this industry, and this is one of the factors to be carefully assessed. Costs in Rhodesia are undoubtedly increasing all the time. Mining at greater depths, tramming and hoisting longer distances, pumping from greater depths, the falling off of grade in some mines as the depths get greater—all these factors are adding to the costs each year on purely technical grounds. Furthermore, in many of the other cost factors there is a continuing process of inflation. Maintenance of these large communities, with their large European and African townships, costs more each year. Costs of power and of railroad transportation are many times greater than a few years ago. The rising standard of living for Africans, which the industry can point to with pride and which indeed is one of its main civilizing achievements, must cost more as time goes on unless it is accompanied by increased productivity, mechanization, and efficiency. All these factors bear on the competitive position of this industry within the world copper picture.

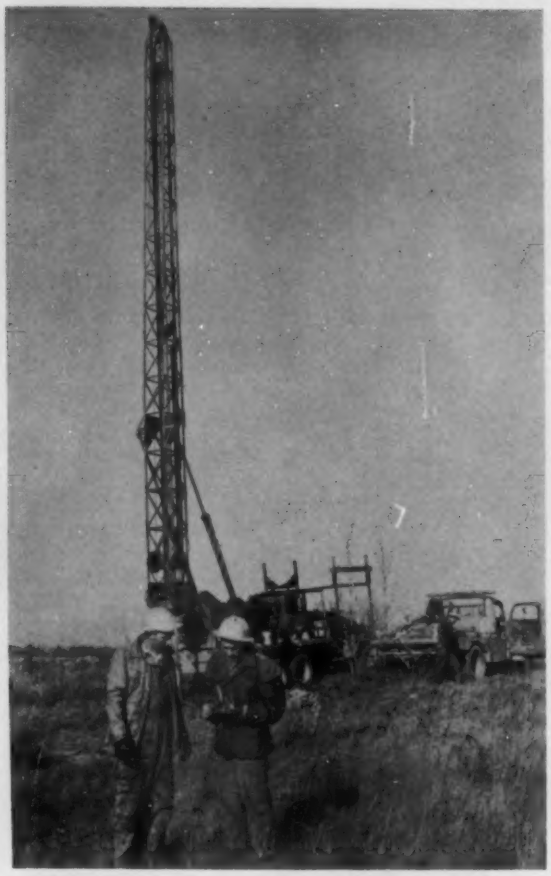
There are, however, two other factors that argue favorably for Rhodesia. One is that similar processes are occurring in some of the other copper producing fields of the world; the other is that in the total cost of production of the Rhodesian mines there is a large element of variable cost, represented principally by the royalties payable. These royalties are based on the price of copper, and if the price of copper were to fall drastically, this element would also fall drastically, providing a certain amount of cushion in bad times. There are other elements of this sort which make it difficult to compare the cost of production in Rhodesia with the costs of other producing fields.

There is one comparison, however, that is commonly made, especially in some sections of the press. This is the statement that the cost of producing copper in Rhodesia is far lower than the cost of producing copper in the U. S. It is high time this myth was exploded. At the risk of over-simplification, it can be stated that during 1955 average costs on the Copperbelt were over 19¢ per lb of electrolytic copper, compared with about 18¼¢ per lb average cost of production within the U. S. The exactness of these figures is open to question, but not the generality.

Finally, we have recently made a study of the cost of producing copper and have been able to obtain published data or estimates for about five-sixths of all free world production in 1955. We find that 52 pct was produced at a cost less than the Copperbelt and 32 pct at a cost above, the Copperbelt accounting for 16 pct of all the known costs by tonnage.

Assuming that the price fell to a point where the Copperbelt operated on a break-even basis, it can be calculated that 38 pct of the same tonnage of world copper would still be produced more cheaply, and 46 pct would be produced at a higher cost. Here again, however, there must be a note of caution, as these figures overlook the probability that other centers might also be able to lower costs.

Mining East Texas Iron Ore



by V. F. Malone

IRON ore reserves of Lone Star Steel Co. cover 56,000 acres in the north basin of the East Texas geosynclinal area near Daingerfield. Ore is almost wholly restricted to the Weches formation of middle Eocene Age. Its resistance to erosion has created the hilly topography of the East Texas area. The ore deposits, in the upper portion of the hills, are usually overlain with residual sand and clay overburden less than 15 ft thick. The ore formation consists of interbedded shallow ocean sediments ranging from pure greensand to fine-grained sands and clays containing a maximum of 70 pct limonite, or siderite, and varying from 2 to 100 ft thick. The iron in this ore originated as iron silicate or greensand in the ocean sediments, and the ore mineral siderite was formed when meteoric waters redeposited the iron under reducing conditions as a carbonate. With weathering and progressive erosion much of this siderite was later oxidized and altered to limonite — yellow to dark brown hydrous iron oxides formed into nodules up to 18 in., embedded in a sandy clay and weathered greensand matrix. Beneath the water table the siderite zone consists of interbedded shale and greensands with thin ledges and nodules of siderite.

Lone Star Steel Co. has proven a 75-year supply of ore, and exploration of reserves and acquisition of new property is not complete.

Mining Methods

Mining is entirely by open cut methods, following exploration data and drillhole analysis to determine depth of overburden, recovery, grade, and cutoff limits.

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Waste Removal: Governed by depth and grade of underlying ore, the economical stripping limit generally is 1 yd of overburden per ton of ore. Engineers stake out the base of ore along the outcrop, and the land is cleared of timber and brush. Depth of cut is marked on stakes and overburden waste is moved to mined-out areas or placed below the base of ore. Overburden is principally a hard-packed sandy-clay material, and a sturdy push tractor is required to load the four rubber-tired 18-yd scrapers used for stripping. Of radically new design, this 365-hp twin-engine tractor utilizes an individual engine, torque converter, torqmatic transmission, and planetary drive for each track. The two power units are joined by a 6-in. shaft that allows the tractor to oscillate vertically over uneven ground. At the top speed of 8 mph one track can be put in reverse while the other is in forward, turning the tractor in the smallest possible space. This powerful push tractor has reduced scraper loading time from 45 sec minimum to 20 sec, and even in hard clays it can heap-load 21 yd on the scrapers. Tire wear on the scrapers has also been reduced, as it is not necessary to pull in gear to help the push tractor. The two newest scrapers also have a torque converter and torqmatic transmission and can be operated by less skilled personnel.

Loading: After the overburden has been removed, the exposed oxidized limonitic ores are mined by 2½ and 3-yd diesel-powered, crawler-mounted

draglines. For several reasons a dragline is preferable to a power shovel:

1) Many of the economic ore seams are only 1 to 3 ft thick. These very thin seams can be mined with a minimum of waste by a dragline, whereas a power shovel could not begin to fill its dipper. It is often necessary to cast out thin waste zones between seams, and this too is better accomplished by a dragline.

2) A dragline can remain at the top of the limonite ore and load trucks on the same level. A power shovel would have to operate at the base of the limonite and on top of the soft clay and shale of the siderite zone. Both loading machine and haulage units become mired in this incompetent material, especially during the rainy winter season.

3) The soft limonite ore does not usually require the positive digging action of a power shovel.

4) Cost of maintenance is reduced, as loading shocks are transferred to the cable and boom and not directly to the machinery.

5) The variable grade and matrices of the ore necessitate operating a number of machines in selected locations to form a proper blend for mill feed. Because of blending requirements these machines seldom load to capacity and the extra production available from a power shovel could not be utilized.

Six draglines are operated each shift, five for loading ore and one for casting and stockpiling ore to decompose shale and pyrite.

Haulage: The daily mill requirement of 15,000 tons of crude ore necessitates a two-shift operation at the mines five days a week. There are two parallel washing circuits in the mill, one treating limonite ores and the second treating siderite. The limonite ore is now being hauled eight miles to the mill. Supplied on a contract tonnage basis, 30 cable-dump trucks of 25-ton capacity travel this long haul at speeds up to 50 mph. Twenty 15-ton rear-dump Euclid trucks, averaging 20 mph, supply the mill with siderite from an area three miles away.

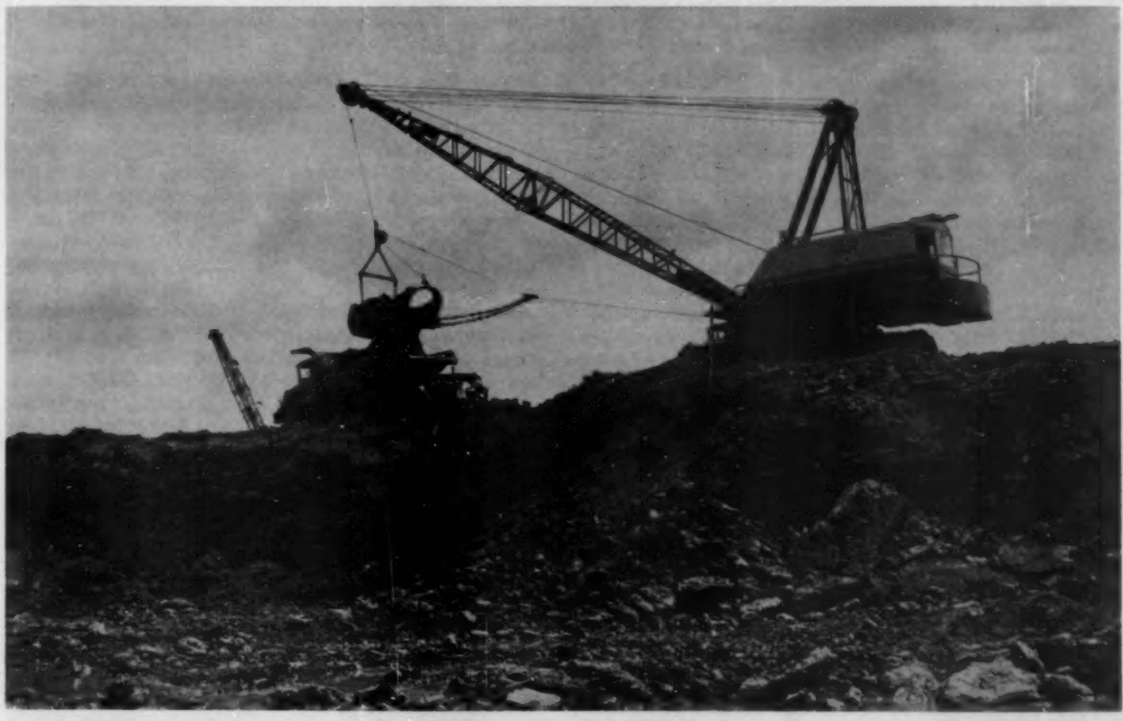
Main haul roads, all three-lane, are well drained. They are constantly sprinkled by six water trucks and patrolled by three road graders. The roads have a base course of sandy clay and a 1-ft layer of fine limonite top dressing. Maximum grade of all haul roads is 4 pct and average grade 2 pct, in favor of the loaded trucks.

History of the Lone Star Steel Co.

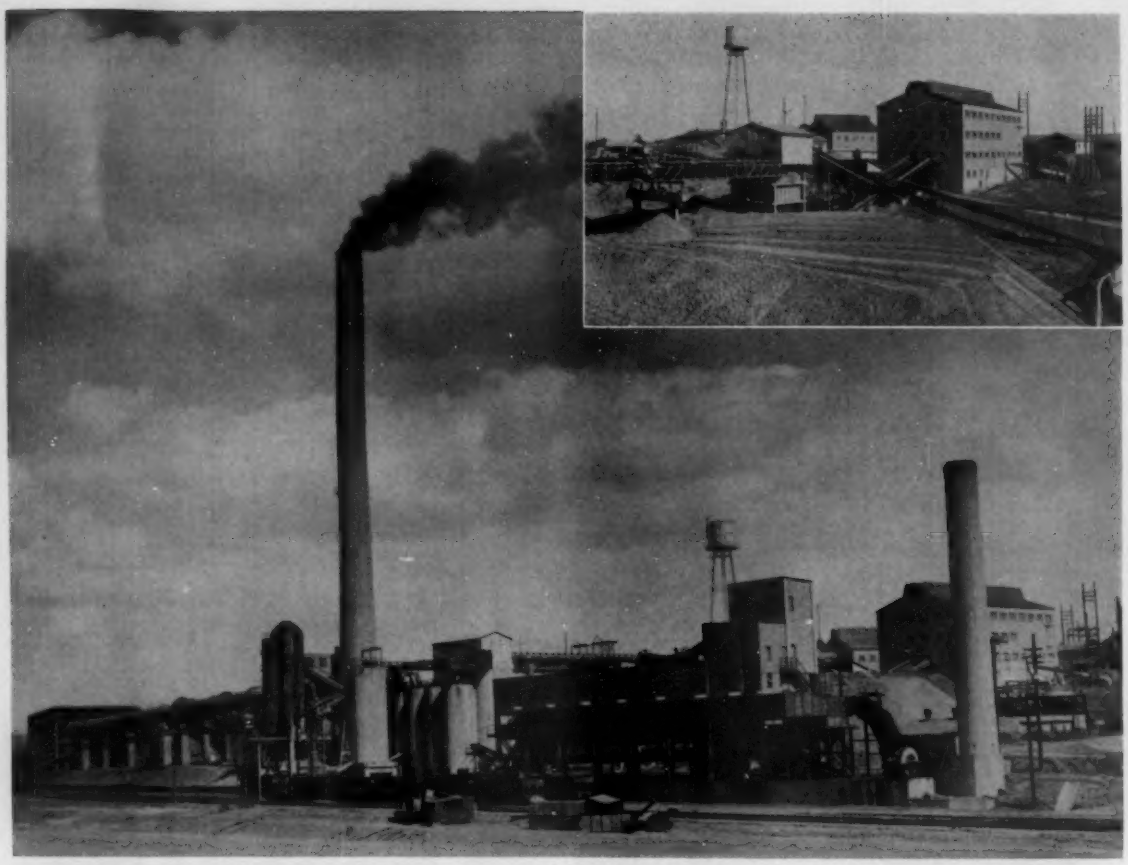
FOUNDED as a wartime source of merchant pig iron, Lone Star Steel Co. is now a fully integrated steel plant producing cast and electric-weld pipe. The E. B. Germany Works, 55 miles southwest of Texarkana, are close to the East Texas iron ore deposits. There is ample water and a ready labor supply. Two hundred miles to the north is an excellent supply of coking coal from three company-owned mines in Oklahoma. Dolomite is shipped from large quarries in central Texas and good limestone is mined in quantity near Fort Worth, 200 miles west of the plant. Manganese is available in the Batesville district of Arkansas and in Mexico. Power is provided from the adjoining East Texas oil field, a steady consumer of pipe products.

Special Mining Problems

Fine Ores: Recovery of fine ores in the −6 mesh size is limited with the present mill. An excess of fines causes high metal losses and possible damage by overloading mill circuits. Percentage of fines in the crude ore is closely controlled by drillhole analysis and by the mine foremen's visual inspection.



Three-yard 71-B dragline, loading siderite ore on 15-ton trucks. The ore bank shows the alternating layers of siderite rock and greensand. The base of siderite ore is too wet to permit hauling operations because it is below the water table.



ABOVE: View of beneficiation plant shows mill in background. In right foreground is the sintering plant and in left foreground are the calcining and roasting kilns. Mill production: 4500 tons of finished product per day. UPPER RIGHT: Plant crushed and washed concentrate stockpile in foreground with No. 1 and No. 2 mill building in background. A hopper and tunnel are located underneath the pile to recover the ore as it is fed to the kilns and sintering plant.

Loading machines must be so placed that fine ore recovery is about 30 pct of total tonnage.

Plastic Clay and Shale: Although the mill requirements for siderite can be supplied by one 3-yd dragline loading efficiently, it is often necessary to operate as many as three loading machines to blend sand-bearing ores with those having a shaley matrix. The tough, plastic clays found with some types of siderite do not break down easily under water pressure or in the blade mills and log washers, and these clays pass through the mills with the concentrates. Adding granular and sandy ores to the shale-bearing ore helps abrade the shale and prevents mud from building up inside the crushers and log washers.

Another successful method is to stockpile the shale-bearing ores above the ground by dragline casting and allow them to air slack and dry. With this procedure it has been possible to handle ores that formerly could not be milled, and although the material must be handled twice it has proved an economic success. About 30 pct of the company's siderite ores now comes from these stockpiles, which must be made three to five months in advance of mining for proper decomposition.

To provide the required daily tonnage of concentrates the mill must operate at about 23 pct recovery. Since the ores vary from 15 to 45 pct recovery, draglines must be carefully located to utilize a maximum quantity of low grade ores and provide a mill feed averaging 23 pct recovery.

Inter-Ore Waste Zone: Most of the orebodies contain waste zones between the ore ledges that must be removed so the ore can be treated at a profit. Mining must be closely controlled by the foreman to follow the cutoff between waste and ore. When the waste zone has been exposed over a wide area, the scrapers and push tractor return to remove the 3 to 12 ft of waste before the lower zones can be mined. Some 300,000 yd of this inter-ore waste must be removed annually.

Hard Ores: Although clay and shale are the main concern with these ores, some siderite forms in thick ledges or with a consolidated greensand that cannot be excavated by power machinery. These hard siderite zones interbedded with plastic clay must be drilled and blasted, and drilling is a problem. Churn drills are too slow, auger drills cannot penetrate the hard siderite, and percussion drills jam in the clay zones. After trials by seven drill manufacturers a tractor-mounted rotary drill using air to eject the cuttings performed satisfactorily with a 4-in. diam, three-leg, carbide-tipped drag bit. This drill completes 500 ft of hole per shift, averaging 15 ft in depth at a cost of $0.15 per ft.

Experimental blasts with various dynamites have shown that best results are obtained with a slow dynamite of ammonium-nitrate base with a detonation speed of 5250 fps. Drillholes are connected with detonating cordeaux using millisecond primacord delays between parallel rows. A powder factor of

Tailings baffle being built across the tailings pond by 18-yd scrapers. Because of the low recoveries, some 3¼ million tons of tailings must be disposed of annually.

0.12 lb per ton has been giving good breakage with a minimum of oversize material. Cost of drilling and blasting has averaged 3¢ per ton of crude ore.

Objectionable Elements: Sulfur and phosphorus are present to some extent in the crude ores. Phosphorus is found in such low concentration that it seldom causes a problem, but sulfur is a completely objectionable element because of its deleterious effect on steel. Unfortunately some of the siderite ores contain up to 1 pct sulfur in gypsum and pyrite. The largest portion of the sulfur is present in pyrite, and in sandy ores or siderite rock it can be discarded as a dioxide in the kilns and sintering plant. The pyrite, however, also occurs in the intermixed shales, and when this cannot be scrubbed out in the mill the calcined product is objectionably high in sulfur.

When these high-sulfur ores have been cast into stockpiles to weather and air slack, results have been gratifying. After about three months of weathering the outer crust of the ore turns brown as the carbonates oxidize. Inner portions of the stockpile reach temperatures of 90°F from the exothermic oxidation of sulfides to sulfates and the chemical combination of the sulfates with calcium and iron anions. The heat of these exothermic reactions also helps dry the admixed shale and clay, making a better mill feed of the stockpile. The pile is said to be *ripe* when in three to five months a quantity of whitish melanterite crystals forms along the base of the pile. This water soluble hydrous iron sulfate is easily rejected in the milling process.

Drainage: Since the siderite ores occur below the water table, drainage can be a problem even in dry weather. With close attention to the ore sections the mining can usually proceed by draining behind the loading machine. Frequent unconformities and perched water tables complicate drainage, and a number of culverts must be placed under mine roads and ditches cast in the base of ore to provide trouble-free all-weather mining. Very little pumping is done.

Beneficiation: The mill flowsheet consists of two parallel and similar circuits, one treating limonite and the other siderite. The crushing, washing, and screening process uses blade mills and log washers, with screens and rake classifiers for the fine material. Fine concentrates are sintered in a downdraft Dwight-Lloyd machine using a fine coke breeze mixture. The coarse limonite is roasted in an Allis-Chalmers rotary kiln at 1400°F to eliminate the physical moisture and most of the water of hydration. The siderite ore is calcined in a Traylor kiln at 2000°F to eliminate carbon dioxide and reduce the sulfur content.

Mill production is 1600 tons per shift and annual production is 850,000 tons of concentrates from some 4 million tons of crude ore. Using these ores the blast furnace produces an average 1200 tons of pig iron per day.

Engineering Enrollment Report

ENROLLMENT of both undergraduate and graduate mineral engineering students rose approximately 11.8 pct over last year to a total of 12,830. Leading again in the enrollment climb was ceramic engineering which increased by about 21 pct. Approximated increases in enrollment of the other mineral engineering categories, in order, were: metallurgical 17.7 pct; petroleum 13.3 pct; geological and geophysical 3.3 pct; and mining proper, the lowest with 2.9 pct.

Total ECPD school enrollment climbed to 242,405—just below the 1947 peak, but 14.4 pct higher than 1955. Engineering enrollments have shown a general increase since 1951, and freshmen enrollments have climbed steadily since 1950.

The small rise in mining enrollments is certainly not an indication of student apathy because the field is crowded. As in previous years, enrollments seem now to be just holding their own. Last year's climb of 13.5 pct was attributed in part to the increased popular interest in mining due to the strong activity in uranium. Even if it is felt that at present there is no serious shortage of mining engineers, it should be pointed out that if enrollments were to sink much below the present level there would be a true predicament. It seems that it is up to industry to decide if it wants a steady flow of candidates for mining degrees.

Slight student interest in the mining field is seen by one authority as stemming from company attitude.[1] He says, "Most of the companies are controlled by men who, although technical graduates themselves, have worked up to top management through the ranks—as miners, timbermen, and supervisors. Even today many of these officials believe sincerely that this is the best training for future managers. This perhaps is true, but management has failed to sell the student on need for a long period of apprenticeship in isolated camps both at home and abroad. Too often the young graduate is not afraid of manual labor; he does object to being lost in the shuffle for months on end."

Grooming for management is not often a sales point well stressed in interesting potential students in the mining field, but it is nevertheless true that many firms hiring engineers choose job candidates with future management openings in mind.

Engineering Student Enrollment Undergraduates and Graduates

Courses	1951 to 1952	1952 to 1953	1953 to 1954	1954 to 1955	1955 to 1956	1956 to 1957
Mining	1,338	1,168	1,089	1,118	1,239	1,275
Metallurgical	2,996	3,085	3,159	3,050	3,421	4,028
Petroleum	2,699	3,448	3,772	4,110	4,195	4,755
Ceramic	667	579	557	626	767	929
Geological	1,027	1,173	1,249	1,370	1,786	1,845
Total Mineral Engineers, U.S.	8,727	9,453	9,826	10,274	11,408	12,832
Chemical	14,079	15,026	15,858	17,097	18,562	20,706
Civil	21,801	22,303	23,075	23,799	26,060	28,076
Mechanical	30,420	32,791	35,097	38,587	43,166	47,857
Electrical	29,966	32,848	37,633	43,305	52,316	61,526
Industrial	6,578	6,643	6,786	7,168	7,747	9,218
Other Engineers	36,123	39,364	43,557	47,224	52,664	62,190
Total Engrs., ECPD	147,694	158,518	171,832	187,454	211,923	242,405
Other U.S. Engrs.	17,943	18,031	21,501	26,960	31,467	34,647
Total U.S. Engrs.	165,637	176,549	193,333	214,414	243,390	277,052
Canadian Engrs.	5,433	5,812	6,894	7,764	8,375	9,620
Total Engrs. U.S. and Canada	171,070	182,361	200,227	222,178	251,765	286,672

Graduate Engineering Enrollment, 1956 to 1957, U. S. and Canada

Courses	Masters	Doctors	Degrees, 1955 M.S.	Degrees, 1955 Ph.D.
Mining	49	6	24	3
Metallurgical	618	256	133	72
Petroleum	170	16	64	4
Ceramic	56	32	29	14
Geol. & Geophys.	123	31	14	2
Total Mineral Engrs. U.S., ECPD	1,016	341	264	95
Chemical	1,977	622	542	136
Civil	2,288	259	804	59
Mechanical	3,667	383	738	61
Electrical	6,857	955	1,128	136
Industrial	2,034	98	339	10
Other Engrs.	2,781	714	683	113
Unclassified	1,367	28	45	—
Total for ECPD Schools	21,987	3,400	4,543	610
Other U.S. Schools	287	2	46	—
Total for all U.S. Schools	22,274	3,402	4,589	610
Canadian Schools	216	75	84	20
Grand Totals, U.S. and Canada	22,490	3,477	4,673	630

Original material for the data included in these tables was supplied by the Journal of Engineering Education *through T. A. Read, head of the Dept. of Mining and Metallurgical Engineering, University of Illinois.*

Reference

[1] N. N. Barish (ed.): *Engineering Enrollment in the United States*, Ch. 18, p. 179, by L. E. Shaffer, New York University Press, New York, 1957.

Undergraduate and Graduate Engineering Enrollment in 225 Schools in the U. S. and Canada, 1956 to 1957

Schools	Courses	Fresh.	Soph.	Junior	Senior	5th Yr. & Others	Total Undergrads	Grad. Students	Grand Total
30	Mining	333	317	269	273	28	1,220	55	1,275
48	Metallurgical	664	790	725	679	287	3,145	883	4,028
22	Petroleum	1,407	1,073	1,060	973	56	4,569	186	4,755
15	Ceramic	224	242	202	159	11	838	91	929
27	Geological and Geophysical	497	458	364	366	6	1,691	154	1,845
142	Total Mineral Engineers U.S.	3,125	2,880	2,620	2,450	388	11,463	1,369	12,832
110	Chemical	5,223	4,645	3,866	3,222	1,120	18,076	2,630	20,706
137	Civil	6,484	6,233	5,636	5,090	2,074	25,517	2,559	28,076
134	Mechanical	10,342	10,773	9,674	8,116	4,864	43,769	4,088	47,857
142	Electrical	13,299	14,046	11,582	9,072	5,665	53,664	7,862	61,526
67	Industrial	1,025	1,532	1,805	2,025	697	7,084	2,134	9,218
217	Other Engrs.	6,409	5,259	4,234	3,629	1,769	21,300	3,605	24,905
93	Unclassified	20,502	3,055	161	42	12,130	35,890	1,395	37,285
151	Total Engrs. ECPD Schools	66,409	48,423	39,578	33,646	28,707	216,763	25,642	242,405
64	Other U.S. Engr. Schools	11,329	7,346	5,032	3,925	6,726	34,358	289	34,647
215	Total U.S. Engineers	77,738	55,769	44,610	37,571	35,433	251,121	25,931	277,052
10	Total Canadian Engineers	3,200	2,230	1,798	1,695	406	9,329	291	9,620
225	Grand Total, U.S. and Canada	80,938	57,999	46,404	39,266	35,843	260,450	26,222	286,672

Electrical Equipment for Processing Plants

by Clark B. Risler and Walter E. Thomas

MILL planning must include electrical drives and a system to supply them. These should be considered at the time metallurgical and mechanical plans are being made. Because it is convenient, flexible, reliable, and economical, electricity is the accepted source for powering mill concentrating equipment. Ore-treating mills have grown to the point where a single mill has been built using 360 motors ranging from 1 to 1000 hp and totaling 50,000 hp. Such a system of electrical drives can be scattered over a square mile and employ 4000 to 220 v.

Drive Motor Characteristics: Since ore processing is predominantly a continuous operation, very few of its drives require wide speed variation after initial adjustment. Consequently squirrel cage, wound rotor, and synchronous alternating current motors are most often used.

Squirrel cage induction motors are constructed with a cast aluminum or brazed copper electrical circuit in the rotor. This elminates multicoil windings, insulating material, and sliprings, providing a strong and trouble-free construction. However, motor performances are limited to predetermined fixed speed-torque characteristics.

Squirrel cage motors provide a fixed starting torque at full voltage which is determined by the resistance of the rotor. The National Electrical Manufacturers Assn. has established several classes of performance characteristics, obtained through varying the rotor design. These classes cover machines rated 200 hp and below.

Squirrel cage motors draw five to six times their rated current momentarily on starting unless reduced voltage starting is employed. Voltage is reduced by inserting a resistor, reactor, or transformer ahead of the motor during the starting. This current reduction is accompanied by an even greater reduction in the starting torque of the motor, lowering its effectiveness to start a drive having high breakaway friction.

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Wound rotor induction motors have multiple coils inter-connected to form the rotor winding. These are connected through sliprings to external rotor resistance. (The terms *secondary winding* and *secondary resistance* are often applied to this rotor electrical circuit.) The ability to control the resistance of the rotor circuit, by drum controller or magnetic contactors, gives the wound rotor motor greater flexibility both in starting and in providing speed control for drives.

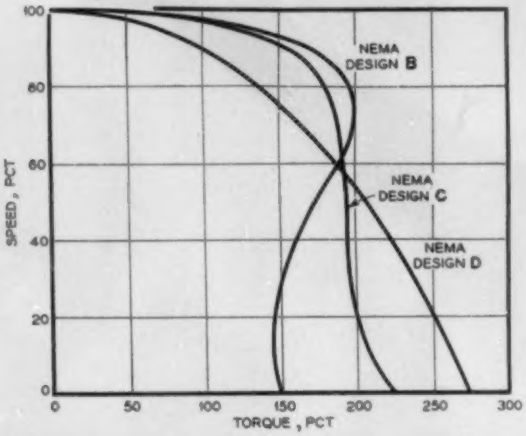
Control of the external resistance permits a series of motor performance curves which can: 1) limit starting torque to a desired value, 2) restrain starting current to that value required to break the drive free, 3) provide the maximum motor torque at standstill if required, 4) accelerate in multiple steps with controlled torque and current peaks.

The requirement for constant motor speed suggests the application of synchronous motors. These motors have a distributed three-phase winding on the stator similar to that used on the induction motors previously discussed. The rotor is constructed with multiple poles having wound coils that are excited by direct current through sliprings. The degree of excitation of this field controls the power factor of the motor. This enables synchronous motors to be operated at leading power factor to compensate for the lagging power factor characteristic of the induction motors. This is a valuable feature in reducing power consumption and distribution costs.

In many cases there is a choice between two motor speeds. A slow-speed motor permits direct coupling between motor and machine. Such an arrangement eliminates the need for additional gearing or belting, but the motor is more expensive. A high-speed motor requires interposing gearing or belting between the motor and machine, but this drive is more compact and the motor is less expensive yet more efficient. However, the alignment problems are greater.

Drive Control Characteristics: On drives with squirrel cage motors, the control equipment is generally of the linestart type in the smaller ratings and the reduced voltage type in larger ratings,

NEMA DESIGN	STARTING TORQUE	BREAKDOWN TORQUE	FULL LOAD SPEED (PERCENT SYNCHRONOUS)
B	120-150%	200-225%	95%+
C	200-225%	200-225%	95%+
D	275%	---	87-95%



TOP: Classification of squirrel cage motor characteristics. BOTTOM: Typical speed vs torque characteristics of squirrel cage motors.

where the power supply will not permit linestarting. In the latter case, the reduction in voltage does not permit utilization of full starting torque.

On drives with wound rotor motors, primary contactors are used for connecting the motor to the power line. Depending on the rating of the motor and the practice of the mill, acceleration can be controlled by a drum controller under the direct supervision of the operator, or automatic acceleration can be obtained with magnetic contactors controlled by accelerating relays actuated as a function of motor current, motor speed, or time.

When synchronous motors are used, the starting and field application control is of either the industrial type (contactors) or of the switchgear type (circuit breakers). The motors are provided with neutral reactor type reduced voltage starting if the line will not permit application of full voltage. Full voltage is preferred to utilize the full starting torque.

When motors are subjected to constant loads they can be protected by thermal or induction-type relays operated by the motor current. These relays incorporate an inverse time delay feature to operate quickly under stalled conditions and permit modest overloads for a short time. Such relays are mounted on the control panel or switchgear and operate in case of overload conditions to shut the motor down or sound an alarm.

Those motors carrying widely fluctuating loads are more difficult to protect. Instantaneous trip relays with an associated time delay can provide protection against stalling or excessive starting time. Most effective protection against overheating can be obtained from a temperature-sensitive relay mounted on the motor frame or windings.

When great inconvenience is caused if drives are stopped under load, for crushers, it is suggested that the overload relay sound an alarm to warn the operator. The drive should then be unloaded before stopping or allowed to run with no load to facilitate cooling. Certainly load should not be reapplied until the cause of the previous overload has been ascertained.

Adequate enclosure of the electrical equipment is most important to successful performance. Open drip-proof motors and NEMA I sheet metal control enclosures usually suffice.

Gyratory and Cone Crushers: Although gyratory crushers have a larger oscillating mass than the cone type, both require relatively high break-away torque when starting unloaded, particularly in cold weather. This is due to the high friction of the eccentric drive and the low viscosity characteristic of the lubricating oil. The large inertia and high friction torque result in a long starting period with an output of 200 pct or more of the motor rating. With the crusher unloaded, when the drive gets up to speed, the motor load is 20 to 30 pct of the motor rating. With the addition of the crushing load, the motor load fluctuates from about 50 to 150 pct rated load,

Classification of Motor and Control Enclosures

Motor Enclosures

Drip-proof: Ventilated openings prevent entry of particles, either directly or by running along a surface, which strike at an angle not exceeding 15° from the vertical.

Splash-proof: Ventilated openings prevent entry of particles, either directly or by running along a surface, which strike the machine at any angle not exceeding 100° from the vertical.

Totally enclosed-Nonventilated: Totally enclosing frame construction with no ventilation openings. Not equipped for cooling by means external to machine.

Totally enclosed-Fan cooled. Totally enclosing frame construction with no ventilation openings. Cooling by forced circulation of air around or through ribs or ducts of frame.

Control Enclosures

NEMA Type 1 (general purpose): Protection against dust and indirect splashing. Not dust-tight.

NEMA Type 1a (semi-dust tight): Additional protection against dust. Not dust-tight.

NEMA Type 2 (drip-tight): NEMA I with addition of drip shields.

NEMA Type 3 (weather-resistant): Protection against rain and sleet.

NEMA Type 4 (water-tight): Protection against weather and hosing down.

NEMA Type 5 (dust-tight): Gasketed to exclude dust.

NEMA Type 6 (submersible): Protection against complete submersion.

Classification of motor and control enclosure. Adequate enclosure of the electrical equipment is most important to successful performance.

Size Opening	Typical Drive Motor, Gyratory Crushers: Type	Hp	Voltage	Speed
14	Squirrel cage	75	440	720
16	Squirrel cage	100	440	720
20	Squirrel cage	150 to 225	440 to 2300	600 to 720
26	Squirrel cage	200	2300	600 to 720
30	Squirrel cage	150 to 225	440 to 2300	600 to 720
36	Squirrel cage	150 to 250	440 to 2300	600 to 720
42	Wound rotor	175 to 275	2300 to 4000	600 to 720
48	Wound rotor	300 to 350	2300 to 4000	600
54	Wound rotor	350 to 400	2300 to 4000	450
60	Wound rotor	450 to 1000	2300 to 4000	450
72	Wound rotor	500	2300 to 4000	450

Size, Ft	Discharge Opening, In.	Typical Drive Motor, Cone Crushers: Type	Hp	Voltage	Speed
2	1/4 to 1/2	Squirrel cage	25 to 30	440	600
3	1/8 to 3/4	Squirrel cage	60 to 75	440	600
4	1/8 to 1/4	Squirrel cage	100 to 150	440	514
5 1/2	3/16 to 1 1/2	Squirrel cage	200	440 to 2300	514
7	3/16 to 1 1/2	Squirrel cage or wound rotor	250 to 300	2300 to 4000	450 to 900

Wound rotor motors are particularly suitable for crushers because they offer higher breakaway torques at standstill with less inrush current than squirrel cage motors.

depending upon the nature of the ore and regularity of the feed. Fluctuations can be minimized by an accumulating hopper and pan feeder.

Wound rotor motors are particularly suitable for crushers because they offer higher break-away torques at standstill with less inrush current than squirrel cage motors. With the wound rotor motor, the inrush current can be limited to the requirements of starting the particular drive, and these motors with their secondary resistors have the necessary thermal capacity of the long accelerating period. However, for the smaller sizes, where the starting current is not a major concern, squirrel cage motors are often used because they are more rugged and are easier to maintain and control.

Roll Crushers: Roll crushers have either single or double crushing rolls. The rolls are spring loaded so that the distance between them can vary as the material being crushed varies in volume. On dual roll crushers the speed of the two rolls is sometimes varied to enhance the crushing effect. This is accomplished by individual drives to each roll. The load as applied to the electric motor fluctuates rapidly and varies directly with the loading of the crusher. The preferred drive is an induction motor which varies in speed inversely as the applied load to permit the inherent mass of the rolls, together with the flywheel effect of any driving pulley, to absorb the extreme peak loads. This not only permits a smaller drive motor but also reduces fluctuations in the power drawn from the line. The latter is highly desirable from the standpoint of voltage regulation, capacity of power supply, and reduction of light flicker.

Roll crushers are driven by induction motors of various sizes. Drives are generally belted to a flywheel of considerable mass. For the smaller drives, the motor is of the high slip squirrel cage type (NEMA D—8 pct or more at full load). Such a motor will reduce speed with applied load to make use of the energy stored in the flywheel. Similar performance can be obtained with a wound rotor motor with permanent resistance in the secondary circuit to provide the drooping speed-torque characteristic. Wound rotor motors can be used on the larger sizes to reduce the current inrush.

Size Rolls (Inches)	Typical Drive Motor, Roll Crushers		
	Type	Hp	Voltage
36 x 16	Squirrel cage	40	440
42 x 18	Squirrel cage	60	440
48 x 20	Squirrel cage	75	440
54 x 30	Squirrel cage	100	440
60 x 30	Squirrel cage	100 to 125	440
72 x 30	Squirrel cage	125	440
72 x 36	Squirrel cage	150	440 to 2300

Size Openings (Inches)	Typical Drive Motor, Jaw Crushers			
	Type	Hp	Voltage	Speed
15 x 30	Squirrel cage or wound rotor	40	440	720
24 x 36	Squirrel cage or wound rotor	75	440	720
30 x 42	Squirrel cage or wound rotor	100	440	720
36 x 42	Squirrel cage or wound rotor	125	440	600
42 x 48	Squirrel cage or wound rotor	150	440 to 2300	600
48 x 60	Squirrel cage or wound rotor	200	2300	600
56 x 72	Wound rotor	250	2300	600
66 x 86	Wound rotor	300	2300 to 4000	450

Roll crushers are driven by induction motors in sizes shown in chart. Jaw crushers use high slip squirrel cage motors in smaller capacities and wound rotor motors in larger ratings.

Northern half of Erie Mining Co. concentrator rod and ball mill installation.

Jaw Crusher: Jaw crushers also make effective use of a flywheel, since the major part of the crushing energy is required during 10° to 15° of each drive-wheel revolution. Thus the drive is permitted to slow down during this small portion of its travel and energy obtained from the flywheel can be replaced during the remaining 345° of the wheel revolution. This permits using smaller induction motors and moderates the power required from the line. Jaw crushers use high slip squirrel cage motors in smaller capacities and wound rotor motors in the larger ratings. Where squirrel cage motors are applied, in view of the large mass, caution must be exercised to insure that the thermal rating of the rotor is not exceeded, since external resistors are not available to dissipate the energy.

Hammer Mill Crushers: Hammer mill crusher drives are characterized by a high starting inertia and a rapidly fluctuating, but continuous, load while crushing. They are generally driven by induction motors—squirrel cage for smaller sizes and wound rotor for the larger. Motors range from 20 to 350 hp with speeds from 1800 to 600 rpm.

Because of the high inertia and friction loads of crushers and the wide fluctuations of the crushing load, crushers are generally started unloaded and the ore load is not added until the drive is up to speed. To supply a motor of ample starting torque to start a crusher when jammed would require an increased motor size.

Rod and Ball Mills: Rod and ball mills are often used for secondary or tertiary crushing service but are more generally considered grinding mills reducing the ore to the range of 4 to 35 mesh in the case of rod mills and up to 200 mesh and finer in the case of ball mills. Once started, these mills are considered a constant speed application whose load varies only slightly with the nature of the material and amount of reduction. In specifying the torque requirements of these mills, consideration may be given to the additional charge due to wear, the possibility of addition of grates, and change in mill speed by change in driving pinion. The major point of concern

in drive selection is the starting requirement, which is generally a torque-position relation in contrast to the customary drive speed-torque consideration.

In evaluating the starting torque requirements of a rod mill, two factors must be considered—break-away torque and peak torque before cascading occurs. Break-away torque is determined by the drive bearing friction, approximately 115 pct, which may be lessened by means of oil-lift on the bearings. The peak torque is determined by the charge in the mill and the angle or height to which it is raised before cascading commences. This peak torque may be equal to about 170 pct motor rated torque and the mill will be at 50 pct speed. Since mill torque is a function of position rather than speed, the motor torque at this speed may be less than 170 pct, but the starting torque is normally recommended to be 200 pct at rated voltage. This will allow for some line voltage drop due to the over-rated current and still provide adequate torque for starting. The mill charge is already tumbling by the time the motor reaches 95 pct speed; hence the maximum load that will occur at pull-in for a synchronous motor is the maximum load that the motor must carry in normal operation. Accordingly, a motor pull-in torque of 125 pct is normally adequate. The pull-in torque greatly affects the motor starting current and keeping it low will minimize the starting current. This in turn will minimize the starting torque reduction due to voltage drop caused by excessive starting current.

Starting torque requirements of a ball mill are very similar to the rod mill, as shown in the following tabulation of motor characteristics:

	Rod Mill, Pct	Ball Mill, Pct
Starting torque	200	180
Pull-in torque	125	120

The necessity of constant motor speed and the fact that a major portion of the installed horsepower exists in the grinding mill drives provides an excellent opportunity to apply synchronous motors. These motors may be operated at 80 pct leading power factor for the general improvement of the plant power factor and distribution efficiency.

On the smaller mills—up to 300 hp—where the power factor correction per motor is not as great, squirrel cage and wound rotor motors are used, and capacitors can be used for power factor correction. The mills are driven through a ring gear on the barrel either directly by a pinion on the motor shaft or a speed reducer in the case of a high speed drive motor. Where no speed reducer is used, motor speed is 120 to 240 rpm.

If it is necessary to open the mill frequently, easy positioning of the entrance manhole can be provided by inching control for the synchronous driving motor. This is complicated equipment using direct current applied successively to multiple connections of the motor terminals to rotate the motor slowly and thus permit stopping the mill where required. Where entry to the mill is not often required, this equipment is not warranted.

Classifiers: The two most popular classifiers in the larger ore concentrating mills are the spiral and rake types. Spiral classifiers provide an essentially continuous load varying only as the characteristics of the ore or the effectiveness of the grinding mill are altered. Such load changes as do occur are gradual. Rake classifiers, if a single rake is used, offer an intermittent load, but with multiple rakes and staggered power strokes the load on the driving motor becomes reasonably constant. With the size of classifiers commonly in use, the load seldom exceeds 25 hp. They are most suitably driven by squirrel cage induction motors with full voltage starting and are connected to the low voltage (230 or 460 v) system of the mill.

Size	Typical Drive Motor, Rod Mills: Type	Hp	Voltage	Speed
4 x 8	Squirrel cage	50	440	—
5 x 10	Squirrel cage	100	440	—
6 x 12	Wound rotor or synchronous	150 to 200	2300	720
7 x 12	Synchronous	200 to 250	2300	720
8 x 16	Synchronous	350	2300	720
9 x 12	Synchronous	450	2300	277 to 1800
9.5 x 13	Synchronous	700	2300	240
10 x 14	Synchronous	900	2300	225
10.5 x 16	Synchronous	800	2300	240
11.5 x 12	Synchronous	1000	2300 to 4000	180
12 x 16	Synchronous	1250 to 1500	2300 to 4000	225

Size	Typical Driving Motor, Ball Mills: Type	Hp	Voltage	Speed
4 x 6	Squirrel Cage	50	440	—
4.5 x 9	Wound rotor	100	440	720
6.5 x 15	Synchronous	300	2300	150
7 x 10	Squirrel cage or synchronous	200	440 to 2300	900
8 x 8	Squirrel cage or synchronous	250	440 to 2300	—
7 x 12	Synchronous	300	2300 to 4000	600
8 x 12	Synchronous	300 to 350	2300	150 to 300
8.5 x 10.7	Synchronous	300	2300	128 to 240
9.5 x 10.7	Synchronous	500	2300	128 to 240
10 x 10	Synchronous	500	2300	257
10 x 12	Synchronous	900	2300	225 to 257
10 x 14	Synchronous	800	2300	240 to 257
11 x 7	Synchronous	450	2300	1800
11 x 11	Synchronous	700	2300	257
11 x 17	Synchronous	1000	2300 to 4000	—
12 x 12	Synchronous	1000	2300 to 4000	240

Typical rating of rod and ball mills.

In the spiral classifier, lifters are provided to free the spiral from the solid material should the drive be stopped with the classifier loaded. Thus the starting load is very light, since only the spiral is being accelerated and the load is gradually increased as the spiral is lowered into the material. Similar arrangements are provided on rake classifiers to raise the frame so that the material moved by the rake is reduced until the rated speed has been reached. With this provision, the classifier can be restarted under loaded conditions without requiring extreme starting torques on the part of the drive equipment or subjecting the mechanism to extreme stress. NEMA design B motors meet the requirements of this duty.

To improve performance of closed circuit grinding where ore characteristics are variable, adjustable speed classifier drives are used. Such performance is obtained from d-c adjustable speed drives using motor-generator sets and d-c driving motors, adjustable speed a-c motors, and a constant speed a-c driving motor with a mechanical system providing variable output speeds. Such systems all involve more initial expense and complication than the constant speed squirrel cage motor drives and are warranted only where special problems exist. Installed horsepower would be about the same as that for the constant speed mill in any instance.

Other methods of classifying material include mechanisms incorporating centrifugal force with hydraulic and pneumatic media. These in general require electrical drives for the pump, blower, or

impeller. Moderately sized squirrel cage motors are used, operated with full voltage starting from the 460-v system.

Since the motor is mounted on top of the classifier, it is required to operate in a dirty, humid location. Drip-proof enclosures provide protection from falling solids and liquids. Insulating materials resistant to moisture should be used. The fact that the motor is operated almost continuously, and thus kept warm and dry, is very favorable. Control equipment can be remote from the motor, and the general purpose control enclosure (NEMA I) is usually adequate. Should the control have to be located at the motor site, a more protective type of control enclosure warrants consideration.

Flotation Cells: Flotation cells present a relatively simple drive problem for the electrical motor. Because of the large number employed in a mill, however, it is extremely important that equipment of high reliability, efficiency, and power factor be obtained. Drive requirements range from ½ to 15 hp, generally at a constant speed of 1750 rpm, operated continuously with essentially constant load. NEMA design B squirrel cage induction motors are very well suited to these drives. They are connected to the 460-v supply system and are provided with full voltage starting from starters remote from the motors. The motors are in most cases mounted with vertical shafts and are connected to the drive by a belt or direct-connected through a speed reducer.

The motors are operated in a very humid atmosphere and under some circumstances are hosed down for cleaning. Motor insulation must have high resistance to moisture and the internal construction of the motors must not trap moisture but permit it to drain out freely. Since the motors are operated continuously it is not so necessary to prevent such moisture from entering. In those few instances where a more thoroughly protected motor is required, totally enclosed fan-cooled motors are used. Such motors incorporate continuous ventilation by air circulated over the frame but keep the internal windings and rotor isolated from the dirt and moisture.

Mechanical Filters: Mechanical filters require an electrical drive for rotating the drum or disk. This calls for a constant speed drive with a NEMA design B squirrel cage motor of 1 to 10 hp. This motor drives the filter through a gear-train. Some of this reduction can be obtained by using a direct-connected speed reducer or gearmotor. The motors are connected to the 230 or 460-v system and are provided with a magnetic full voltage starter.

Where the product is of varying nature, adjustments in the operating speed may be desired. In such instances adjustable speed drives can be used. These can be either of the d-c adjustable voltage type with a separate motor-generator set driving a d-c motor, or a constant speed a-c motor with a mechanical variable speed transmission. The a-c motor arrangement is more often used.

In these drives the motors are relatively well protected from moisture or dirt and open drip-proof motors have proved adequate.

Accessory drives are required to pump the liquids, create the appropriate vacuum and pressure, and remove the cake once it has been discharged from the filter. Pumps, compressors, and conveyors are all considered in their respective sections.

Mechanical Screens: Perhaps the most common screen is the inclined or flat vibrating mesh. Such screens generally require a constant speed drive of ½ to 25 hp and are driven by squirrel cage induction motors. The motors run at 1750 rpm and are connected to the machine by V-belts to isolate them from the extreme vibration. Due to the requirements of starting the drive under load, it has been found desirable to use NEMA design C squirrel cage motors for this application. These motors provide high starting torque while maintaining a reasonable limit on the inrush current drawn from the power line. Such motors are linestarted.

Where extreme conditions of dust or dirt are anticipated, totally enclosed fan-cooled motors warrant consideration. However, open drip-proof motors usually provide adequate protection from falling material, and with regular *blowing out* the motors provide satisfactory service.

Magnetic devices using alternating current to create oscillatory motion for the screens have found considerable favor in some applications, particularly those handling small particles. These drives employ no motor. With these devices, it sometimes is desirable to superimpose a direct current voltage on the alternating current. Direct current for this purpose can be obtained either from a static rectifier such as selenium stacks or a-c to d-c motor-generator set driven by a squirrel cage motor. The size of this equipment is closely related to the material to be handled and the lifts involved—hence an estimate of range of ratings is not included.

A third kind of screen employs a series of eccentric rollers spaced to permit the fine material to pass through while moving the coarser material to the discharge end. These rollers are powered by a chain drive from a single motor in the range of 7½ to 20 hp. Performance of these screens depends on the speed at which the rolls are operated. Hence, package-type adjustable voltage drives are used, with a speed range of 8 to 1. An a-c to d-c motor-generator set driven by a squirrel cage motor energizes the d-c driving motor. The drive is connected to the machine by V-belt to isolate the motor from the vibration. The motor-generator set, since it will start under no load and has relatively small horsepower capacity, would be controlled by a magnetic full voltage starter and be operated from the 460-v system.

Conveyors: One of the most important of the accessory equipments in a concentrating mill is the conveyor system which interconnects equipment processing material in the dry state. These conveyors have motors ranging from 5 hp to 300 hp and motor speeds ranging from 900 to 1800 rpm. Conveyor drives are powered from the 460-v system.

Comparison of Filters

Disk Type				Drum Type		
Size		Motor		Size	Motor	
No.	Disk Diam., Ft	Hp	Voltage	Lg—Diam., Ft	Hp	Voltage
2	6	1	220 to 440	4 x 3	1	220 to 440
6	6	2	220 to 440	6 x 10	2	220 to 440
6	8	3	220 to 440	8 x 8	3	220 to 440
6	12	5	220 to 440	10 x 10	5	220 to 440
12	12	8	220 to 440	14 x 18	10	220 to 440

Mechanical filters require an electrical drive for rotating the drum and disk. This calls for a constant speed drive with an NEMA design B squirrel cage motor of 1 to 10 hp, as indicated on chart.

in drive selection is the starting requirement, which is generally a torque-position relation in contrast to the customary drive speed-torque consideration.

In evaluating the starting torque requirements of a rod mill, two factors must be considered—break-away torque and peak torque before cascading occurs. Break-away torque is determined by the drive bearing friction, approximately 115 pct, which may be lessened by means of oil-lift on the bearings. The peak torque is determined by the charge in the mill and the angle or height to which it is raised before cascading commences. This peak torque may be equal to about 170 pct motor rated torque and the mill will be at 50 pct speed. Since mill torque is a function of position rather than speed, the motor torque at this speed may be less than 170 pct, but the starting torque is normally recommended to be 200 pct at rated voltage. This will allow for some line voltage drop due to the over-rated current and still provide adequate torque for starting. The mill charge is already tumbling by the time the motor reaches 95 pct speed; hence the maximum load that will occur at pull-in for a synchronous motor is the maximum load that the motor must carry in normal operation. Accordingly, a motor pull-in torque of 125 pct is normally adequate. The pull-in torque greatly affects the motor starting current and keeping it low will minimize the starting current. This in turn will minimize the starting torque reduction due to voltage drop caused by excessive starting current.

Starting torque requirements of a ball mill are very similar to the rod mill, as shown in the following tabulation of motor characteristics:

	Rod Mill, Pct	Ball Mill, Pct
Starting torque	200	180
Pull-in torque	125	120

The necessity of constant motor speed and the fact that a major portion of the installed horsepower exists in the grinding mill drives provides an excellent opportunity to apply synchronous motors. These motors may be operated at 80 pct leading power factor for the general improvement of the plant power factor and distribution efficiency.

On the smaller mills—up to 300 hp—where the power factor correction per motor is not as great, squirrel cage and wound rotor motors are used, and capacitors can be used for power factor correction. The mills are driven through a ring gear on the barrel either directly by a pinion on the motor shaft or a speed reducer in the case of a high speed drive motor. Where no speed reducer is used, motor speed is 120 to 240 rpm.

If it is necessary to open the mill frequently, easy positioning of the entrance manhole can be provided by inching control for the synchronous driving motor. This is complicated equipment using direct current applied successively to multiple connections of the motor terminals to rotate the motor slowly and thus permit stopping the mill where required. Where entry to the mill is not often required, this equipment is not warranted.

Classifiers: The two most popular classifiers in the larger ore concentrating mills are the spiral and rake types. Spiral classifiers provide an essentially continuous load varying only as the characteristics of the ore or the effectiveness of the grinding mill are altered. Such load changes as do occur are gradual. Rake classifiers, if a single rake is used, offer an intermittent load, but with multiple rakes and staggered power strokes the load on the driving motor becomes reasonably constant. With the size of classifiers commonly in use, the load seldom exceeds 25 hp. They are most suitably driven by squirrel cage induction motors with full voltage starting and are connected to the low voltage (230 or 460 v) system of the mill.

Size	Typical Drive Motor, Rod Mills			
	Type	Hp	Voltage	Speed
4 x 8	Squirrel cage	50	440	—
5 x 10	Squirrel cage	100	440	—
6 x 12	Wound rotor or synchronous	150 to 200	2300	720
7 x 12	Synchronous	200 to 250	2300	720
8 x 16	Synchronous	350	2300	720
9 x 12	Synchronous	450	2300	277 to 1800
9.5 x 13	Synchronous	700	2300	240
10 x 14	Synchronous	900	2300	225
10.5 x 16	Synchronous	800	2300	240
11.5 x 12	Synchronous	1000	2300 to 4000	180
12 x 16	Synchronous	1250 to 1500	2300 to 4000	225

Size	Typical Driving Motor, Ball Mills			
	Type	Hp	Voltage	Speed
4 x 6	Squirrel Cage	50	440	—
4.5 x 9	Wound rotor	100	440	720
6.5 x 15	Synchronous	300	2300	150
7 x 10	Squirrel cage or synchronous	200	440 to 2300	900
8 x 8	Squirrel cage or synchronous	250	440 to 2300	—
7 x 12	Synchronous	300	2300 to 4000	600
8 x 12	Synchronous	300 to 350	2300	180 to 360
8.5 x 10.7	Synchronous	300	2300	128 to 240
9.5 x 10.7	Synchronous	500	2300	128 to 240
10 x 10	Synchronous	800	2300	257
10 x 12	Synchronous	900	2300	225 to 257
10 x 14	Synchronous	800	2300	240 to 257
11 x 7	Synchronous	450	2300	1800
11 x 11	Synchronous	700	2300	257
11 x 17	Synchronous	1000	2300 to 4000	—
12 x 12	Synchronous	1000	2300 to 4000	240

Typical rating of rod and ball mills.

In the spiral classifier, lifters are provided to free the spiral from the solid material should the drive be stopped with the classifier loaded. Thus the starting load is very light, since only the spiral is being accelerated and the load is gradually increased as the spiral is lowered into the material. Similar arrangements are provided on rake classifiers to raise the frame so that the material moved by the rake is reduced until the rated speed has been reached. With this provision, the classifier can be restarted under loaded conditions without requiring extreme starting torques on the part of the drive equipment or subjecting the mechanism to extreme stress. NEMA design B motors meet the requirements of this duty.

To improve performance of closed circuit grinding where ore characteristics are variable, adjustable speed classifier drives are used. Such performance is obtained from d-c adjustable speed drives using motor-generator sets and d-c driving motors, adjustable speed a-c motors, and a constant speed a-c driving motor with a mechanical system providing variable output speeds. Such systems all involve more initial expense and complication than the constant speed squirrel cage motor drives and are warranted only where special problems exist. Installed horsepower would be about the same as that for the constant speed mill in any instance.

Other methods of classifying material include mechanisms incorporating centrifugal force with hydraulic and pneumatic media. These in general require electrical drives for the pump, blower, or

impeller. Moderately sized squirrel cage motors are used, operated with full voltage starting from the 460-v system.

Since the motor is mounted on top of the classifier, it is required to operate in a dirty, humid location. Drip-proof enclosures provide protection from falling solids and liquids. Insulating materials resistant to moisture should be used. The fact that the motor is operated almost continuously, and thus kept warm and dry, is very favorable. Control equipment can be remote from the motor, and the general purpose control enclosure (NEMA I) is usually adequate. Should the control have to be located at the motor site, a more protective type of control enclosure warrants consideration.

Flotation Cells: Flotation cells present a relatively simple drive problem for the electrical motor. Because of the large number employed in a mill, however, it is extremely important that equipment of high reliability, efficiency, and power factor be obtained. Drive requirements range from ½ to 15 hp, generally at a constant speed of 1750 rpm, operated continuously with essentially constant load. NEMA design B squirrel cage induction motors are very well suited to these drives. They are connected to the 460-v supply system and are provided with full voltage starting from starters remote from the motors. The motors are in most cases mounted with vertical shafts and are connected to the drive by a belt or direct-connected through a speed reducer.

The motors are operated in a very humid atmosphere and under some circumstances are hosed down for cleaning. Motor insulation must have high resistance to moisture and the internal construction of the motors must not trap moisture but permit it to drain out freely. Since the motors are operated continuously it is not so necessary to prevent such moisture from entering. In those few instances where a more thoroughly protected motor is required, totally enclosed fan-cooled motors are used. Such motors incorporate continuous ventilation by air circulated over the frame but keep the internal windings and rotor isolated from the dirt and moisture.

Mechanical Filters: Mechanical filters require an electrical drive for rotating the drum or disk. This calls for a constant speed drive with a NEMA design B squirrel cage motor of 1 to 10 hp. This motor drives the filter through a gear-train. Some of this reduction can be obtained by using a direct-connected speed reducer or gearmotor. The motors are connected to the 230 or 460-v system and are provided with a magnetic full voltage starter.

Where the product is of varying nature, adjustments in the operating speed may be desired. In such instances adjustable speed drives can be used. These can be either of the d-c adjustable voltage type with a separate motor-generator set driving a d-c motor, or a constant speed a-c motor with a mechanical variable speed transmission. The a-c motor arrangement is more often used.

In these drives the motors are relatively well protected from moisture or dirt and open drip-proof motors have proved adequate.

Accessory drives are required to pump the liquids, create the appropriate vacuum and pressure, and remove the cake once it has been discharged from the filter. Pumps, compressors, and conveyors are all considered in their respective sections.

Comparison of Filters

Disk Type				Drum Type		
Size		Motor		Size	Motor	
No.	Disk Diam, Ft	Hp	Voltage	Lg—Diam, Ft	Hp	Voltage
2	6	1	220 to 440	4 x 3	1	220 to 440
6	6	2	220 to 440	6 x 10	2	220 to 440
6	8	3	220 to 440	8 x 8	3	220 to 440
8	12	5	220 to 440	10 x 10	5	220 to 440
12	12	5	220 to 440	14 x 18	10	220 to 440

Mechanical filters require an electrical drive for rotating the drum and disk. This calls for a constant speed drive with an NEMA design B squirrel cage motor of 1 to 10 hp, as indicated on chart.

Mechanical Screens: Perhaps the most common screen is the inclined or flat vibrating mesh. Such screens generally require a constant speed drive of ½ to 25 hp and are driven by squirrel cage induction motors. The motors run at 1750 rpm and are connected to the machine by V-belts to isolate them from the extreme vibration. Due to the requirements of starting the drive under load, it has been found desirable to use NEMA design C squirrel cage motors for this application. These motors provide high starting torque while maintaining a reasonable limit on the inrush current drawn from the power line. Such motors are linestarted.

Where extreme conditions of dust or dirt are anticipated, totally enclosed fan-cooled motors warrant consideration. However, open drip-proof motors usually provide adequate protection from falling material, and with regular *blowing out* the motors provide satisfactory service.

Magnetic devices using alternating current to create oscillatory motion for the screens have found considerable favor in some applications, particularly those handling small particles. These drives employ no motor. With these devices, it sometimes is desirable to superimpose a direct current voltage on the alternating current. Direct current for this purpose can be obtained either from a static rectifier such as selenium stacks or a-c to d-c motor-generator set driven by a squirrel cage motor. The size of this equipment is closely related to the material to be handled and the lifts involved—hence an estimate of range of ratings is not included.

A third kind of screen employs a series of eccentric rollers spaced to permit the fine material to pass through while moving the coarser material to the discharge end. These rollers are powered by a chain drive from a single motor in the range of 7½ to 20 hp. Performance of these screens depends on the speed at which the rolls are operated. Hence, package-type adjustable voltage drives are used, with a speed range of 8 to 1. An a-c to d-c motor-generator set driven by a squirrel cage motor energizes the d-c driving motor. The drive is connected to the machine by V-belt to isolate the motor from the vibration. The motor-generator set, since it will start under no load and has relatively small horsepower capacity, would be controlled by a magnetic full voltage starter and be operated from the 460-v system.

Conveyors: One of the most important of the accessory equipments in a concentrating mill is the conveyor system which interconnects equipment processing material in the dry state. These conveyors have motors ranging from 5 hp to 300 hp and motor speeds ranging from 900 to 1800 rpm. Conveyor drives are powered from the 460-v system.

Most of the conveyors will be of the rubber belt type while a few, such as pan feeders, are of metal construction. Large belt conveyors need particular attention to the starting torque to prevent overstressing the belt, which considerably shortens belt life. To break loose and accelerate the average loaded belt requires 150 pct of the rated torque of the motor. The starting torque may be even higher in the case of long, slightly downhill belts where the operating horsepower is very low. It is desirable to limit the accelerating torque peaks to 160 pct to avoid overstressing the belt.

On the smaller belt conveyors, ranging up to 60 hp, squirrel cage motors are generally employed. While NEMA design C motors have been applied, there has been a recent shift to the use of NEMA design B motors. NEMA design B motors are general purpose designs and more readily available from stock. This availability compensates for the less desirable torque characteristics of lower starting and higher accelerating peaks. These smaller belts have more liberality in their construction. The motors are started directly across the line to achieve their full starting torque. Once the conveyor is up to speed the loads will vary from 30 to 150 pct under short time overload conditions.

For larger conveyors, requiring motors of 100 hp and above, wound rotor motors are most often employed. These are used because the torque during the accelerating period can be held within the limits necessary for good belt life. To accomplish this, multiple steps of acceleration are employed, ranging from 7 to 20 depending upon the size of the drive and the mass of the conveyor belt system. The seven or eight step starters are of the full magnetic type with accelerating contactors under automatic control of current, motor speed, or time limit relays. Where more points are required, motor-operated drum controllers adjust the secondary resistance as the drive accelerates.

Recently a drive has been placed in operation using a combination of saturable reactors and a resistance in the secondary of a wound rotor motor to provide only two steps of acceleration and at the same time hold the torque within the desired limits. This arrangement represents a major simplification of the control and, by reducing the number of steps, eliminates the stress pulses on the belt during the accelerating periods.

In another development, squirrel cage motors are available with accelerating torques in the range from 150 to 160 pct. Such drives permit full voltage starting of the motors and simplify the electrical drive equipment required for conveyors up to 200 to 250 hp.

Cranes: Aisle cranes are necessary in any concentrating mill to place equipment and to assist in the maintenance and adjustment. Because cranes are used on a standby rather than a continuous basis, low first cost combined with good reliability are the primary requirements.

These cranes employ motors ranging from 5 to 10 hp on the trolley drive and up to 40 hp (a few larger) on the hoist motion. With the advances made in alternating current crane control, the use of a-c operated cranes for such mill duty is almost universal. To reduce the initial cost of cranes, manually operated drum controllers can be used, although in the long run these will require more maintenance than full magnetic equipment.

For many years a-c cranes have employed mechanical load brakes. These devices, when lowering a load, provide a braking action released by positive driving torque of the wound rotor motor. This results in positive load on the motor at all speeds in either direction. With such load, the speed of the wound rotor motor can be adjusted by simple, multi-step, reversing control.

More recently crane drives have been introduced using an eddy current brake to replace the mechanical load brake. Excitation of the eddy current brake is varied along with the control of the motor secondary to provide a hoist drive with good speed regulation and give the operator a variety of operating speed points in each direction of travel.

Crane control using a saturable reactor in the primary of the wound rotor motor eliminates the need for mechanical and electrical load brakes. This system of control gives excellent maneuverability for the operator, permitting him to float a load in mid-air or creep it up or down as required. The advantages of this for installation and maintenance work on heavy machinery are immediately evident.

Where direct current cranes are desired, hoist or mill type d-c motors should be employed with manual or magnetic control, as the economic situation dictates. In cases of plant expansion, additional d-c generating capacity may be required for the additional d-c cranes. In such instances installation of a-c cranes should be considered.

Pumps: As water is vital to operating concentrating plants, it is not surprising to find in pump drives the second largest installed motor capacity. Pump drives range from 1/3 to 1500 hp, at motor speeds from 585 to 3465 rpm.

Centrifugal pumps are the most popular. They present a relatively low starting torque unloaded and starting torques not exceeding 100 pct even under loaded conditions. High-speed, constant-speed drives are usually required, permitting NEMA design B squirrel cage induction motors. These motors are started with full voltage except in the higher ratings, which use reduced voltage starting of either autotransformer or reactor type. On larger pumps with synchronous motors, care should be taken to assure adequate motor torque if the pump is to be started under load.

Requirements for reciprocating pumps are about the same, except with regard to starting under load. In cases where this is necessary, starting torques 200 to 225 pct of the rated torque of the motor are required and motors of special design should be used—generally squirrel cage or wound rotor motors in the larger sizes.

Where demand fluctuates it is not uncommon to use squirrel cage motors for driving a majority of the pumps, while driving one pump of the bank by a wound rotor motor. Speed of the wound rotor motor can be controlled to some extent by adjusting the secondary resistance. Initially this is more expensive, but depending on the intended method of operation, it can prove more economical.

Pump drives are generally energized from the 460-v system but should be operated from higher voltages when they require 200 hp or more.

Compressors and Blowers: Compressors and blowers have the same drive requirements as pump drives of comparable ratings. The motors range from 10 to 1500 hp, as in the case of powerhouse induced draft fans. On the smaller sizes linestarted squirrel cage motors are used, operated from the

Typical Ore Processing Plants

Product	Capacity Raw Ore Short Tons per Hr	Total Installed Hp	Power* Consumption Kw-Hr per Ton	Main Supply Voltage	Prime Power Source	Emergency Power Source
Potash	150	3,500	11.5	4.16 Kv	Purchased	10 Kw
Potash	500	9,700	12.0	12.47 Kv	Purchased	250 Kw Diesel
Copper	310	10,000	16.0	46.0 Kv	Purchased	300 Kw Diesel
Copper	1250	29,300	13.0	2.3 Kv	Generated (Steam)	
Copper	1250	36,163	18.9	115.0 Kv	Generated (Steam)	
Copper	1330	38,800	17.0	2.3 Kv	Purchased	
Copper	1880		14.1	13.8 Kv	Generated (Steam)	
Copper	1880		13.7	13.8 Kv	Generated (Steam)	
Iron	96	5,350	21.4	2.4 Kv	Purchased	
Iron	129	5,313	15.5	2.4 Kv	Purchased	
Iron	1770	50,000	21.2	13.8 Kv	Generated (Steam)	Purchase 25,000 Kw

* Per ton raw ore.

The major sources of supply for these longer blocks of electrical energy are the public utility systems.

Distribution Transformers

Single-Phase

High Voltage Ratings	Low Voltage Ratings	Kva Ratings: Liquid-Immersed	Kva Ratings: Dry Type
2400, 4160, 4800	120/208 Y, 240, 480	3 to 833	3 to 167
6900	120/208 Y, 240, 480	3 to 1250	
7200			
7620	2400, 4160, 4800	50 to 2500	
12000	120, 240, 480	5 to 500	
13200			
13800	2400, 4160, 4800	50 to 2500	

Three-Phase

High Voltage Ratings	Low Voltage Ratings	Kva Ratings: Liquid-Immersed	Kva Ratings: Dry Type
2400, 4160, 4800	120/208 Y, 240, 480	9 to 1500	9 to 500
6900	120/208 Y, 240, 480	15 to 2500	150 to 500
7200			
7620	2400, 4160, 4800	250 to 3750	
12000	120, 240, 480	15 to 2500	
13200			
13800	2400, 4160, 4800	250 to 7500	

Single-phase and triple-phase distribution transformer ratings.

460-v system. When sizes are larger or when a degree of speed control is desirable, wound rotor motors assume a more prominent place. To obtain the desired pressure, it is possible to adjust the motor-operated secondary drum controller by manipulating the automatic magnetic control by a pressure-sensitive system. Such use of a wound rotor motor for speed control is economical over a speed range of 2 to 1.

Load Requirements: Since ore and processes differ, power required for concentrating will differ and each ore must be evaluated individually. With the harder ores, about one half the power consumed is used in the grinding process. This points up the tremendous importance of proper selection of electrical drives for rod and ball mills.

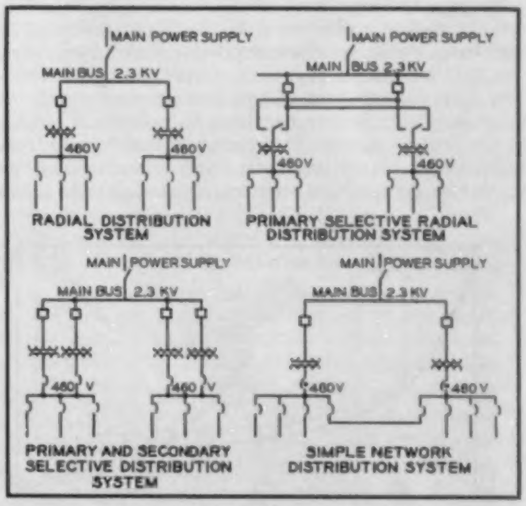
Power Sources: The major sources for these large blocks of electrical energy are the public utility systems. Location of the mill with respect to the power generating stations and major transmission lines will determine the voltage at which power will be received. Incoming voltage will range from 2.4 to 115 kv and will be three-phase, 60-cycle. Twenty-five cycle power systems are in the minority and are diminishing.

In isolated locations or where process steam or emergency power are needed, all or part of the electrical energy can be generated at the mill. Main power generators are driven by steam turbines and are installed in sizes up to 40,000 kw operating at 13.8 kv.

Complete continuity of service cannot be guaranteed by any public utility. An emergency source of power must be provided to handle extremely critical loads when power is shut off—materials that will solidify if allowed to stand idle. Diesel-driven generators, 100 to 1000 kva, are often used. These will generate at a voltage comparable to the main plant distribution system: 2.4, 4.16, 6.9, 13.8 kv.

Distribution: The main plant substation, which may be provided by the utility or the mill, will include primary disconnect switches, oil or air-insulated outdoor transformers, and outdoor metal-clad switchgear of the drawout type. This switchgear contains feeder breakers to serve the several major power feeders to the plant or to the adjoining mine and any totalizing metering. Continuity of service can be improved and maintenance of the transformers performed without complete mill shutdown if two or more substation transformer banks are used. In the larger plants this becomes economically practical.

From the substation the energy is transferred to the plant by overhead transmission lines or underground cables. Choice is based on economy and continuity of service. Overhead lines are cheaper but more subject to outage due to weather hazards. Where overhead lines are used it is often the practice to parallel them and include switching at either end to permit ready transfer from one line to another in case of trouble. Underground cables are much less vulnerable to power outages but cable faults are more difficult to locate and repair. The correct size of conductors can be obtained by reference to wire tables issued by the cable manufacturers.



Upper right and lower left sketches illustrate two modifications which incorporate selectivity on the primary and the secondary side, overcoming the disadvantages of the simple radial system.

At the mill the power is placed on a main or plant bus. The self-generated power of the plant may also be fed to this bus. Where the mill processes are isolated it may be desirable to have several buses, one for the crushing plant, another for the milling and concentrating building, and a third for other power requirements around the mill.

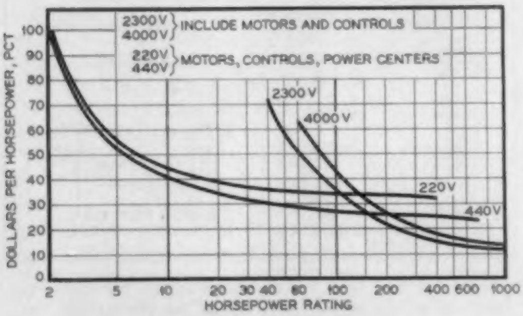
To provide greater continuity of service, this main bus may be sectionalized, each section being fed by an individual feeder from the main substation. The various sections are tied together by normally open bus-tie breakers that are selectively closed, in case of an incoming feeder fault, to maintain power supply to all mill operations. Critical loads are tied to one section of this main bus, which is designated as the emergency bus. In case of failure of the main power source this section of bus is disconnected from the other sections and is supplied by the emergency generator.

From the main bus the power is fed to the various load centers by the plant primary distribution system. A radial system, the cheapest to install, is the one found in most plants. It has limitations, however, in regard to flexibility and continuity of service when faults develop in feeders, transformers, or switching equipment. The primary selective radial system has multiple feeders in parallel to the load centers, at which locations selective switching permits operation from either of the available feeders. With a secondary selective system, continuity is assured by duplicating power center transformer facilities.

The greatest flexibility and protection against distribution system power failures is obtained by the secondary network system. If this is installed in its ultimate form, feeder lines and transformers will have enough overload capacity to carry full plant load with a feeder or transformer out of service. Duplication of equipment, with resultant economies, may further justify such an installation.

Power Centers: The plant distribution voltage is often suitable for the larger drives but must be stepped down to an appropriate voltage for drives of lesser horsepower. In most plants the primary system voltage ranges from 2.4 to 12 kv and the secondary system is 460 v.

To supply these low voltage loads a transformer facility must be connected to the plant distribution bus through some disconnecting means, frequently one that includes a degree of overcurrent protection. The low voltage side of the transformer should be provided with feeder breakers to distribute energy to the several drives. To secure economic power distribution it is advisable to have a multiplicity of these transformer facilities, each situated near localized centers of load. Unitized Power Centers combine a transformer of appropriate type and capacity with an integrally mounted high voltage breaker or disconnect switching equipment plus the low voltage feeder breakers. This equipment is coordinated, standardized, and preassembled to provide a compact, economical and effective functional unit.



Influence of operating voltage on drive cost.

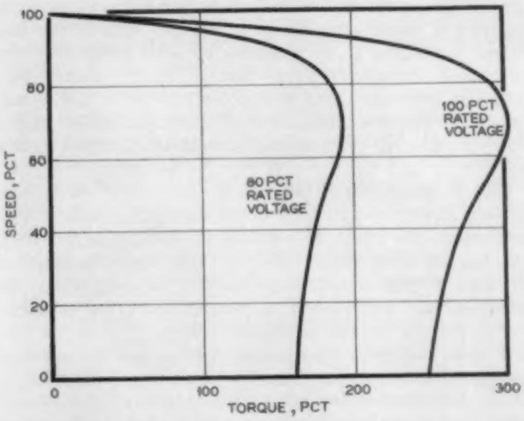
Standard Power Center Ratings

High Voltage	Low Voltage	Kva Ratings: Indoor Unit, Dry Type	Kva Ratings: Outdoor Unit, Indoor Unit, Liquid Type
2400	208/120	45	
4160	240	75	
4800	480	112.5	112.5
	600	150	150
7200		225	225
		300	300
12000		500	500
13200		750	750
13800		1000	1000
		1500	1500
		2000	2000

Table lists ratings of available power centers and serves to determine size of sections of the electrical system.

Power Centers can be located outdoors or indoors according to the economics of plant construction and space utilization. For outdoor locations, completely weatherproof equipment is provided ready for mounting on the concrete base. Liquid-filled transformers are generally used. Sealed dry-type transformers are available in ratings up to 3000 kva. Where indoor location is desired, the lighter weight and freedom from any fire hazard or oil maintenance favor the use of air-cooled transformers. Where liquid-filled transformers are desired for indoor location, the use of Askarel fluid eliminates the fire hazard, but the hazard of explosion and release of toxic gases remains. Sealed dry-type transformers eliminate the hazards.

Possible plant expansion should be considered when location and capacity of these Power Centers are determined. Matching low voltage switchgear can be added to accommodate additional feeders if the initial transformer has adequate capacity. A very flexible arrangement is to locate the high voltage disconnecting means and transformer outdoors, throat-connected to the center of low voltage switchgear inside the mill. This permits installation of a

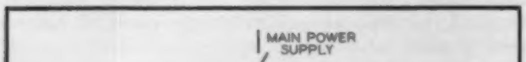


Graph shows the effect of reduced line voltage on speed-torque characteristics of squirrel cage motors.

second or larger transformer outdoors and comparable expansion of the low voltage feeder switchgear with a minimum demand for inside space.

It has proved desirable to assemble controls for a group of motors into a common control center. Each controller is mounted in an individual metal compartment for ready access and sequential interlocking and interconnection. Squirrel cage motor controllers of full voltage or reduced voltage type at 440 v and below can be so mounted. Starters can incorporate air circuit breakers or disconnect switches as desired. Additional feeder breakers, lighting distribution panelboards, and 480/120-v transformers can be included. Control centers require only connection of main power and motor leads at installation, thereby materially reducing installation cost and time. Usually wound rotor and synchronous motor controllers require individual floor-mounted cubicles.

Voltage Regulation: In planning a plant distribution system it is extremely important to select equipment adequate to maintain proper voltage regulation. Poor voltage regulation can be a continuous handicap to a plant from the standpoint of motor starting, motor performance, and possible future expansion. A serious reduction in starting and pull-out torques is associated with a voltage drop of 20 pct. This also applies to the pull-out torque of a wound rotor motor and the starting torque of a synchronous motor. The pull-out torque of the synchronous motor is influenced in direct proportion to the voltage reduction. Not only is performance of the motor reduced but control equipment may be caused to malfunction and cause accidental stoppage of entirely unrelated electrical equipment. Reduced illumination is caused by conditions of low voltage or poor voltage regulation. Light flicker warrants consideration when these conditions occur suddenly and are frequently repeated.



Simplified single line diagram of a typical ore-processing plant as might be developed during the basic planning stages.

Power Factor: Maintenance of the power factor of the plant system at a high level will contribute to improved voltage regulation, better utilization of the plant distribution system, and reduced power billing charges. In most ore concentrating plants a sufficient amount of power is used in the rod and ball mills, which can be driven by synchronous motors to obtain the desired power factor correction. Use of capacitors attached to the distribution system at selected locations can also provide the power factor correction. Caution must be exercised in applying such capacitors that undue voltage rise does not occur at times of light load. However, in most concentrating plants, the operation is continuous and periods of light load do not occur. Capacitors are available with provision for automatic switching which will cut them in and out as a function of time, line voltage, or power consumption. These may be required in extremely rare cases.

Interruption Capacity: With the loads grouped into blocks not exceeding 500 kva at 240 v or 750 kva at 480 v, the interrupting capacity of standard low voltage air circuit breakers is adequate. Depending on the stiffness of the distribution system, control centers connected to Power Centers rated at more than the above capacities usually require extra impedance in the circuit to limit fault duty on the standard molded cast control center breakers. This impedance may take the form of extra impedance built into the transformer or current-limiting reactors built into the control centers. Current limiting fuses can also be used to limit fault currents.

System Grounding: With an ungrounded system the first line to ground fault causes no disturbance. This is a worthwhile feature for locations where stoppages cannot be tolerated or where an active and mobile maintenance force is not available. However, as soon as the fault is established, full line to line voltage exists between the ungrounded lines and ground. Thus, a condition has been created whereby a ground fault from another line will constitute a full line to line fault, with resulting interruption of production. Ground detecting equipment is available to notify of the existence of the first fault, which should be cleared at the earliest opportunity.

Were a system employed having a grounded neutral, the first line to ground fault constitutes a single phase fault and will immediately interrupt power flow on the faulted feeder. This makes location of the fault easier. Upon the occurrence of a line to ground fault the potential from the remaining two phases to ground remains about normal, thus providing lower insulation stress than in the case of the ungrounded system.

The need for a grounding system is not as imperative for personnel safety in a mill, where machine frames can be firmly grounded to the building structure, as in distribution systems for portable mining equipment where the assurance of a solid ground for the apparatus is not certain. There is no definite trend to either system in existing mills. On 2400 or 460-v systems, there is very little difference in overall cost between the two systems, since the cost of ground detecting equipment is offset by the cost of special wye-connected transformers. On 4160-v systems, the transformer secondaries are wye-connected as standard.

Exploring and Mining for Salt

by Leo E. Read and Charles H. Jacoby

IN diamond coring salt beds to evaluate deposits, special techniques are applied to standard *slim* hole drilling to obtain a representative sample of the water soluble sodium chloride. Industrial consumers generally require a run-of-the-mine material of 98.0 pct sodium chloride. Since no commercial beneficiation has yet been devised to upgrade the lower quality salt beds, the only processing is crushing and screening to the size required by the customer. Coring salt sections has recently become important not only in dry mining, but also in the development of brine cavities by hydraulic fracturing and the formation of *jugs* for storing liquid petroleum products.

Drilling Fluid: The fluid used in coring salt beds in New York, Ohio, and Michigan is a thoroughly saturated brine made from 3.0 lb rock salt per gal of make-up water. This mined rock salt, −4 mesh +10 mesh, is dissolved in a lixator, a double-bottomed cone hopper that turns fresh water to fully saturated brine.

In coring these salt beds, no allowance is made for other soluble constituents because of the similarity between these cores and products of the Detroit and Retsof mines. Percentages of soluble elements in the rock salt are 98.0 pct NaCl, 0.65 pct $CaSO_4$, and 0.05 pct $CaCl_2$ and $MgCl_2$.

The calcium sulfate of rock salt goes into solution more slowly than sodium chloride, so that where brine maintenance or a new brine solution is required, drilling fluid must be recycled after the drill rods are inserted almost to the bottom of the hole. In ascending along the walls of the drillhole, the brine is usually in contact with anhydrite and gypsum, which help to build up the $CaSO_4$. It has been observed in the field that although the salometer may show 100° salometer brine, there is occasionally some leaching in the first few feet of cored salt. When brine is properly recycled prior to drilling, leaching is eliminated. Top salt is extremely important in roof studies where the salt is to be mined hydraulically.

Manufacture and Maintenance of Brine Drilling Fluid: Unless a lixator is used, one of the most difficult tasks in the field is to manufacture and maintain a clean saturated brine as a drilling fluid. Several steps are needed to accomplish this.

After the NX casing is set, a section of anhydrite or dolomite rock 10 to 20 ft deep is drilled with clear water. This allows any particles of scale on the casing or rods to be knocked or worn off before brine is used.

A *T* joint of pipe is screwed to the upper end of the string of casing so that return flow is discharged directly onto a wire sieve to eliminate foreign floating matter such as string, sticks, and grease. The brine passes into a sump, where some of the coarse cuttings are deposited. A small pump picks up the drilling fluid from the sump and lifts it into a wooden trough, lined with baffles that help to settle out the medium sized cuttings before the fluid flows to the final settling tank.

This steel settling tank, holding 500 gal, is divided by a perforated steel plate. Fine cuttings settle out in the forward compartment. The suction hose from the rig picks up the brine from the rear compartment and returns it down the hole through the rods, completing the normal cycle of the drilling fluid.

Brine salinity is constantly checked to insure full saturation. Should a leak develop in or under the casing, or should an aquifer be encountered large enough to dilute the brine below the necessary 100° salometer, then brine maintenance is started. Maintenance consists of plugging the perforations in the plate dividing the steel tank, picking up the brine from the forward compartment, and introducing it to the lixator. Lixator gravity feeds the saturated liquor back to the rear compartment of the steel tank, where the suction hose of the rig picks it up.

Return circulation is required; therefore, if a zone of lost circulation is encountered, it may be

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Specially designed 2½-cu yd Marion shovel loading a 20-ton electric battery-driven Euclid bottom-dump truck.

necessary either to reduce the size of the hole and pull the casing and ream past the point of lost circulation, resetting the NX casing, or to cement the lower section of the hole where the cavity or crevice was encountered.

After penetrating thick strata of material other than salt, it is often necessary to change the brine completely, clean the tanks and troughs, and make up a fresh, clean brine. Brine containing small suspended particles of rock erodes the salt core by mechanical abrasion to form a tear drop indentation. This is true even when a double-tubed rigid core barrel is used. The double-tubed barrel and those swivel types with relief ports in the inner barrel have been improved in the field by plugging the ports so that water included in the rods does not cascade over the core as the rods are pulled. The core should not only show fine horizontal striations from the bit diamonds, but should also give 100 pct salt recovery.

Generally speaking, the shorter the core, the better the chances of complete recovery, but in the case of salt it is good practice to pull at banded impurities within the bed even if this means drilling more than a recommended 10 ft.

In northeastern U. S. the laminated impurities in salt beds can often be correlated for many miles. A pulling point can sometimes be anticipated in a bed if there are other exploration holes with which to correlate these bands. Where no correlation is possible, close observation of the penetration rate may show a *pull point*.

Even though core diameter may be full size, it is extremely difficult to pull this core, as salt is very slippery—the purer the salt, the slicker the core. In all cases a new core lifter should be used. As an added precaution a light sprinkling of tungsten carbide powder may be brazed to the inside of the core lifter wedges. In the field wedges can be roughed with a cold chisel to help the grab of the lifter.

After the section of salt is cut, a mark should be made on the rods to locate the bottom of the hole prior to pulling. The hoisting plug is then screwed into the rods and a gentle strain applied to the line until a snap is felt and the tools start moving up the hole. At this point the rods should again be lowered to the bottom and the mark indicating the bottom checked.

The practice of burning the bit into the salt rather than using a core lifter is poor, since the higher quality salt is more easily destroyed than the rocky impurities.

Casing: Depending on near surface conditions, a 4 to 6-in. string of standard black iron pipe is set or driven through the overburden of soil. Generally a 3⅝-in. hole is drilled through the aquifers to the top of the evaporite section to prevent fresh water from coming in contact with the salt beds.

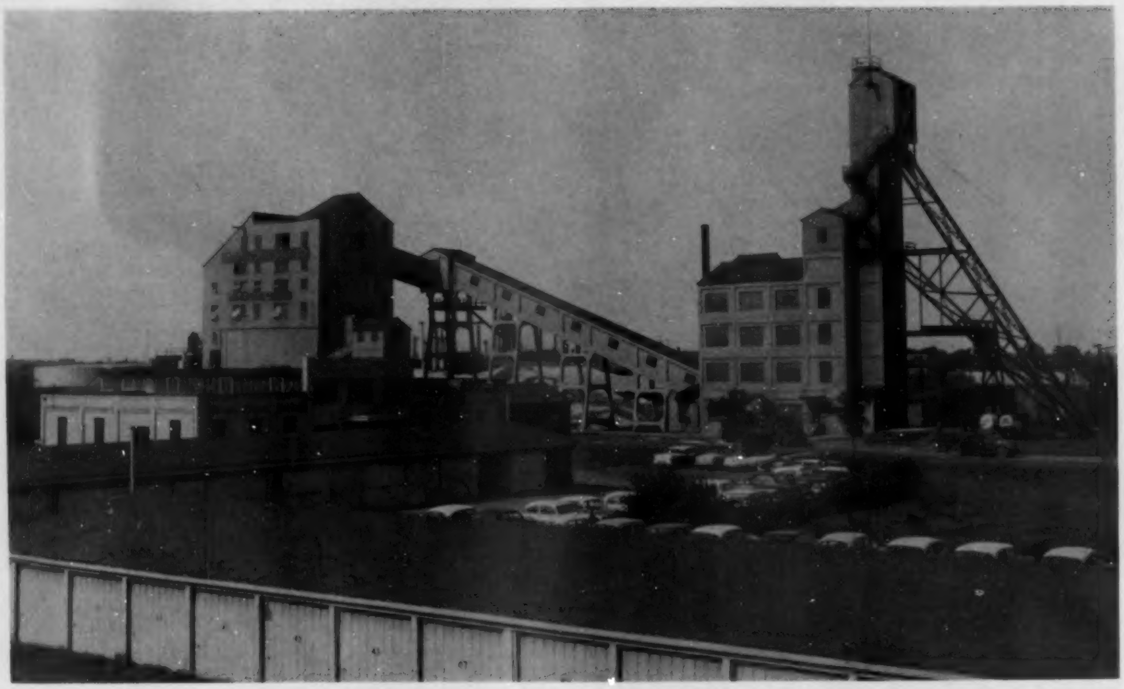
A good casing point can be selected by checking the penetration rate. If cored material is found unsuitable despite the slow rate of penetration at the point selected, then the rods should again be lowered and another point chosen.

Use of a split collar vs a steel shoe on the bottom of the casing depends on the material at the depth where the casing point is located.

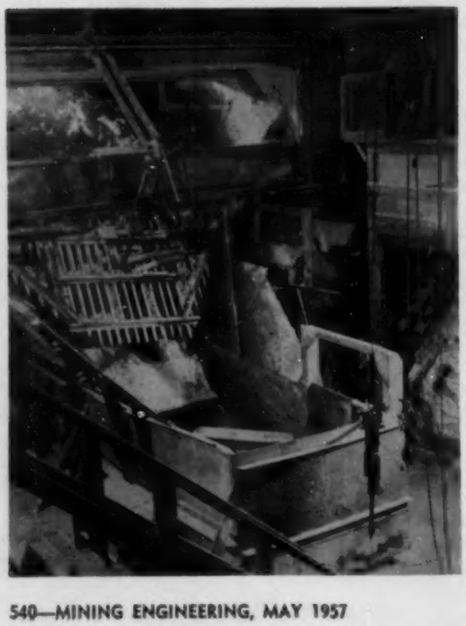
After the string of NX casing is set, the hole is continued as an NX or 3-in. hole recovering a 2⅛-in. core. Sometimes it is possible to obtain a satisfactory salt core in the smaller diamond bit sizes, but for several reasons an NX hole is preferable.

Freshly cored salt may be heard to pop and split after it has been removed from the core barrel and placed in the boxes. This is particularly true of deep coring where a crystalline type of salt has been penetrated.

Deviational Survey: After each drillhole is completed, a deviational survey of the hole is made to determine the direction and degree of inclination.



ABOVE: International Salt Co. surface facilities, which are within city limits of Detroit. RIGHT: Twenty-ton bottom-dump Euclids traveling along the 60-ft haulageway. These are salt roads maintained by a standard road grader.



LEFT: At the top of this picture is the roadway for the bottom-dump Euclids. The salt may be seen in the 60-ton bin. Material from this bin is pan fed to the crusher. ABOVE: This small electric shovel is feeding salt from storage to a hopper-inclined belt which discharges back to the mainline belt.

When mining is contemplated, this predetermines pillar locations in the vicinity where the drillhole has penetrated the salt bed.

This barrier of salt surrounding the drillhole is an added protection against possible seepage of fresh water down the hole, even though all drillholes are cemented by lowering the rods to a point near the bottom and pumping cement through the rods as they are pulled.

General Geology: The evaporite beds of Michigan, Ohio, and New York are flat-lying deposits. The generally accepted theory is that salt deposition was brought about by evaporation of a landlocked intermittent sea. Although gradational zones of anhydrite, dolomite, and salt with some argillaceous contamination predominate, the salt beds are readily discernible from gamma-neutron logs. Such logs are of particular value in geological correlations where leaching of the upper salt beds occurred.

To fulfill various economic aspects such as shallow hoisting depths, water transportation, adequate rail facilities, and a short haul by consumers, it has often been necessary to drill near the salt terminus. Actually each salt bed has been deposited and leached independently, so there are many terminus lines in the same area, usually in stair step order.

Water in the Salina beds, except near the terminus line, is limited to connate water with small quantities of included gas.

Mining at Detroit: The mine at Detroit is on the southeastern periphery of the great Michigan Salt Basin. Here the room and pillar system is used. An undercutter adapted from the coal industry develops rooms 20 ft high in a 60-ft face of salt. Traveling about 7 in. per min, this undercutter forms a 7-in. kerf, 10 ft deep, along a marker lamination in the salt. Occasional masses of included rock or sections containing quantities of silica are encountered in the marker zone, slowing speed and causing considerable bit damage. Alloy steel bits have replaced the carbide type for this reason.

Since fines, or −10 mesh material, are a constant problem owing to degration of salt particles during processing and handling, side shearing has been avoided. It is believed that if both undercutting and side shearing were practiced the fines would be excessive. Past experience has shown that 60-ft rooms can be driven, allowing about 70 pct extraction, provided 3 ft of roof salt is carried in the back. The 22-ft high ceilings are scaled with a Barret hoist and steel bars. There is little or no pillar rashing. Convergence gages have been installed throughout the mine to record any roof movement.

Generally three vertical holes per 10-ft slice are drilled in the roof to check the thickness of overhead salt. If there is a wet spot an extra hole is drilled to relieve pressurized connate water. Pockets of connate water vary from a few gallons to several thousand.

The face drilling pattern consists of five rows of seven holes. Horizontal spacing is 10 ft with rib holes drilled on each side. The lower holes are loaded with four sticks of 1¾ x 24-in. 45 pct dynamite, the top holes with four sticks of Grasselli. The Grasselli in the top row of the roof of holes is an added protection in shooting the 900-ton breaks. Rows are fired with steel 50 to 500 m-sec delay caps, which not only slab toward the kerf but also reduce vibration—an important consideration in conducting operations under a populated area. Steel wires in the caps are eliminated with magnets rather than copper so that there is no chance for copper contamination of the salt. This safeguard is of particular importance to the consumer, as copper-contaminated salt will burn hides during the tanning process.

Specially designed 2½-yd electric shovels load into 20-ton battery-electric, bottom-dump Euclids, which carry mine-run salt to the primary crusher over 4500 ft of salt roads. Roads are maintained by a standard road grader with occasional sprinkling to aid compaction, thus forming a hard, high-speed haulageway.

Face salt is dropped into a bin and pan fed to a spike-toothed single roll crusher, selected after tests proved its ability to produce a minimum amount of fines. The crushed product, −6-in. rock, is fed to a conveyor belt that hauls it to an underground crushing and screening plant 2900 ft from the primary crusher.

This preparation station crushes and screens the salt into four size ranges: 1) FC, −10 mesh; 2) CC, −0.301 in. +10 mesh; 3) No. 1, +0.301 in. −0.420 in.; and 4) No. 2, +0.420 in. −½ in. Relative percentages of each product are: No. 2, 10 pct; No. 1, 15 pct; CC, 52 pct; and FC, 23 pct. This means that final screening carries 75 pct of the total product, 23 pct of which passes through a 0.073-in. opening. Capacity of these Rotex fine screens is 1½ sq ft of screen surface per ton per hour of salt feed. Because of the greater resistance of the impurities to degration during comminution, grades containing the larger particles are of a lower chemical analysis. Moisture inherent in the Detroit salt eliminates all dust problems.

Products from the preparation station are stored in a 3000-ton surge bin. There has been some difficulty in size segregation, since larger sizes roll down the slopes of the pile and the fines compact at the center near the drawpoint. These compacted fines will stand in vertical faces and occasionally must be sliced off with a scraper hoist. Where size specifications are important this can be a serious problem. Storage from this bin bottom-feeds onto a belt and is carried 3300 ft to the skip pocket. The belt has an optional discharge to underground storage by stacking conveyor. Salt is reclaimed from this 100,000-ton underground storage by small electric shovels, which feed into portable hopper-inclined belts that in turn discharge the salt back onto the mainline belt. These facilities level out both daily production and seasonal demands. Winter demands are roughly two and a half times those of summer.

At present, face drilling is being done with Scranton electric drills using auger-type rods and tungsten carbide bits. These four rigs mounting four drills are to be replaced by a hydraulic jumbo carrying four Fletcher drills. It is expected that the increased drilling speed and mobility of one jumbo will compensate for the capacity of the four rigs.

The counterbalanced skips, loading from two skip pockets, are of 10-ton capacity. Spillage from the skips and pockets is cleaned by fresh water jets that dissolve the salt. This water, together with any seepage from shaft walls, collects in the shaft sump and is pumped to surface in a single stage. The Aldrich pump is capable of handling 75 gpm from the depth of 1160 ft.

After the salt is on surface, 50 pct is shipped by rail, 25 pct by truck, and 25 pct by boat. Boat shipments are limited to the Great Lakes shipping season. Outside storage is provided for some 75,000 tons of snow and ice control.

Recent Developments in Rock Drilling at Chino Mines

by D. D. McNaughton

IN providing 65,000 tons of broken muck per day for shovel operation in a large open pit copper mine, drilling equipment and efficient use of that equipment is of prime importance. To improve existing drilling efficiencies, a large electric rotary drill capable of drilling 12-in. holes was purchased in May 1955. At Chino 96 pct of the blasting is done with 12-in. holes because: 1) the large holes break the optimum amount of material to reduce track-shifting to a minimum, 2) better fragmentation is obtained from a relatively short column of powder, and 3) longer spacing results in greater tonnage broken per foot drilled.

From 1955, when it was purchased, through October 1956, the rotary drill has drilled 95,701 ft at a rate of 167.4 per shift in various locations and types of ground encountered in the mine. (This includes moving time and all other delays while a crew is on the machine.) The machine has been worked two shifts per day, seven days per week, and has been available 68 pct of this time.

For purposes of comparison, the following churn drill results are included for 1955 and 1956 through October: 405,434 ft have been drilled; the rate was 51.56 ft per shift; availability of the churn drills is not a factor in this comparison, as there are churn drills in position to work at all times.

Two-man crews are used on either the churn drill or the rotary drill, but the cost of drilling a foot of rotary drillhole is approximately 60 pct of the cost per foot of churn drillhole.

The rotary drill uses normal pit power, supplied at 4400 v ac. This is transformed to 440 v on the machine. In drilling, a 125-hp, a 50-hp, and a 15-hp motor are run simultaneously.

The machine is large, but towing with a track-laying bulldozer and a rigid triangular towbar has proved successful. Weight of the drill is 35 tons, height 47 ft with the mast up, and 18 ft 6 in. with the mast lowered, length 37 ft, and width 14 ft. Trolley power must be shut off each time the drill is towed under a trolley, as clearance with the mast down is less than 1 ft.

Blasthole rotary drilling has lagged behind oil well drilling, chiefly because there is no economical method of cutting exhaust. Chino's rotary rig is equipped with a 1200-cfm air compressor, which supplies air at 60 psi down through the drill rods to blow the cuttings out of the hole. An air velocity of 2600 fpm is attained in the hole.

Tricone bits of 12 or 12¼-in. diam are used. The cone bearings on these bits are cooled by the air

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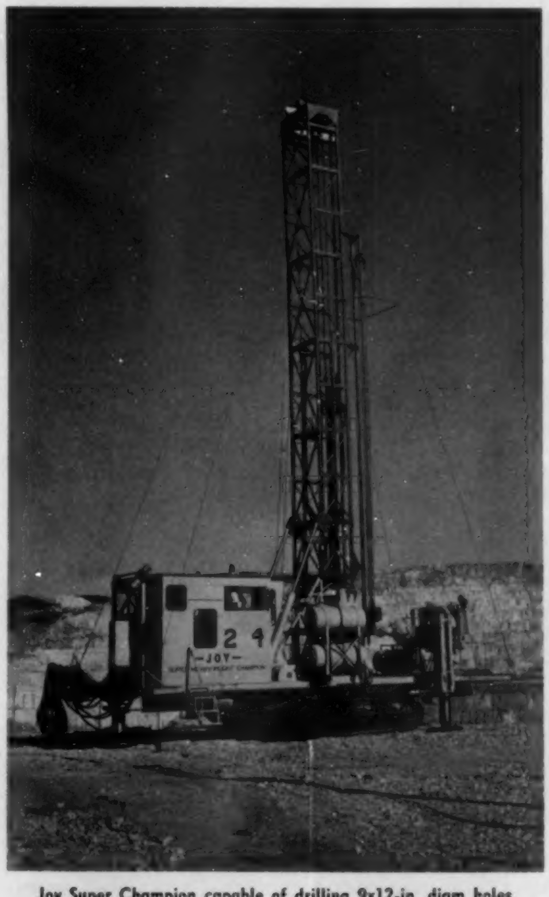

Joy Super Champion capable of drilling 9x12-in. diam holes. Cost of drilling a foot of rotary drillhole is approximately 60 pct of the cost per foot of churn drillholes.

This mobile drill has been called a *stinger*, a *wasp*, or a *sewing machine* for *stitching* banks. Economy lies in the ability to move the compressor, drill water tools, and men as a unit.

stream, and it is believed that high feed pressures plus the technique of allowing the air to blow on the bit bearings while the feed is retracted contribute to bit life, which averages 1600 ft.

Dry drilling with air exhaust introduced a dust control problem. This was solved by utilizing the differential pressures, or the Venturi effect, of the moving air stream to inject a fine spray of water into the air stream in amounts just sufficient to control the dust. No pump is necessary for this water injection. The dry drilling effects a water saving which is important in an arid climate. The pile of cuttings deposited around the finished hole is a source of excellent stemming for the blasting operation, and the quantity is more than sufficient.

Rotary drilling has obviously proved successful at Chino, and two more large rotary drills have been purchased and are being set up for operation.

Another innovation in drilling at Chino has been a self-contained air drilling unit used for primary drilling where space does not permit large diameter blastholes and for secondary drilling. This mobile drill has been called a *stinger*, a *wasp*, or a *sewing machine* for *stitching* banks. A motor and chassis with front and rear wheel steering was purchased from one manufacturer, a hydraulically operated jib from another, and a 4-in. drifter and carriage from a third manufacturer. These were combined with a used rotary air compressor of still another make. The result was a self-contained drilling unit with a higher road speed and mobility than those available on the market as a unit. Since the average toe or cresthole shot for this unit consists of about eight holes, mobility is most important. Drilling assignments for the machine may be two miles apart. The economy lies in the ability to move compressor, drill, water, tools, and men as a unit. Since the operator is a combination air driller and powderman, he may be required to blast his own holes if the occasion warrants, thus effecting another saving in transportation. At present, tungsten carbide bits and sectional rods are being used on this machine.

The mobile air drill has been in operation only a month. During this time it has drilled 2950 ft of 2⅝-in. diam hole at a rate of 116.2 ft per shift worked, with some time spent in blasting included. During the same time, 11,712 ft of hole ranging from 3-in. to 1⅞-in. diam were drilled by conventional machines at a rate of 71.9 ft per shift. No costs are available as yet on the mobile drill, but a considerable saving is expected because of its greater drilling efficiency.

It is anticipated that the overall cost of breaking ground at Chino will be lowered considerably by these improved drilling methods.

Cement and Aggregates for Shielding in Atomic Energy Plants

Using high-density concrete often reduces plant costs and improves operation efficiency.

by Harold S. Davis

SURROUNDING the nuclear core of an atomic energy plant there are usually one or more thick walls of concrete, as required to protect instruments and personnel from the harmful effects of nuclear radiations. Sometimes these massive walls are of ordinary concrete weighing about 150 pcf. To reduce wall thicknesses, concrete weighing 200 to 350 pcf may be used. Such high densities are obtained by using natural aggregate processed from heavy ore, or by using steel slugs or iron shot in concrete. Mix data for a number of high-density concretes are summarized in Table I.[1]

High density at low cost is of prime importance in shields designed to absorb gamma rays. On the other hand, biological shields located near the reactor core must attenuate neutrons as well as gamma rays. In general, a biological shield should contain: 1) heavy elements to slow down high energy neutrons and to absorb gamma rays, 2) either light elements or hydrogenous materials to moderate neutrons of intermediate energy, and 3) materials to absorb neutrons once they have been slowed down to thermal energies. Some shield materials, iron and water for example, are effective in one or more of the above ways. On the other hand, some otherwise excellent shield materials have certain undesirable radiation properties that limit the ways or number of places they can be used. For example, when iron absorbs neutrons it emits secondary gamma rays of high energy. On the other hand, boron absorbs neutrons avidly without producing high energy gamma rays. In spite of its high cost, boron is sometimes used in concrete to minimize production of secondary gamma rays. In some shielding applications it is necessary to avoid materials that become radioactive when subjected to neutron bombardment, continuing to give off high energy gamma rays for long periods after being removed from a neutron field.

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When heavy aggregates are selected for construction of concrete reactor shields, consideration must be given to their radiation properties as well as to their physical properties and cost.

Aggregates for Shielding Concrete: Of 60 minerals with a specific gravity greater than 3.5, about 10 are commercially available. Of these barite, magnetite, limonite, and geothite are the most suitable for making concrete aggregate. The physical properties of some of the best available aggregates are presented in Table II.[2] It will be noted that barite aggregate should have a specific gravity greater than 4.2, magnetite greater than 4.4 and limonite greater than 3.4. To meet these density requirements, high grade ore is required. Other heavy ores such as hematite, taconite, ilmenite, arsenopyrite, chromite, psilomelane, and galena are of interest but have not been used widely in concrete shields. Steel punchings, sheared bar stock, and iron shot are used to obtain concrete densities above 250 pcf. Ferrophosphorus, a byproduct of the phosphorous industry, makes excellent shielding concrete. However, some heavy slags and smelter byproducts are highly reactive with the other ingredients of concrete. Colemanite sand has been used in special concrete as a source of boron. Boron frits, formed by fritting borax with silica, is less soluble than colemanite but more expensive. Concretes that contain boron do not harden normally.

General Requirements for Heavy Aggregates: Heavy aggregates should be clean, strong, inert, and relatively free of deleterious materials that impair the strength of concrete. They should not contain appreciable amounts of thin, elongated pieces and should be well graded from coarse to fine. As a general guide, the size distributions and desirable qualities of aggregates for ordinary concrete can be used in writing specifications or for processing heavy aggregates. (See ASTM Designation C33, for example.)[3] However, allowances must be made for the natural characteristics of the heavy ore being used.

Here steel punchings and bar ends are being mixed and blended with limonite and magnetite aggregate. Ore is washed in bins out of photo at left, conveyed separately to storage bins at center, weighed, and mixed together in mixer, just to right of center, elevated in tower at right, passed over ⅜-in. vibrating screen, discharged into buckets, and hauled by truck to the reactor site.

Barite has a hardness of 3 to 3.5, and during crushing and handling it tends to powder. Some iron ore is brittle, or highly crystalline in structure, and breaks into smaller pieces when handled. As long as the resulting concrete is not subjected to severe abrasion, the relative aggregate softness does not preclude its use in concrete shields.

Typical grading specifications for coarse and fine aggregates are presented in ASTM Designation C33. Because of difficult placement conditions, oversize must often be minimized. In some cases, grading requirements for heavy aggregates will be more stringent in order to produce concrete of good workability and maximum density from a given type of aggregate. On the other hand, reasonably well graded crusher fines can often be used if they do not contain too much dust of low density. Fine aggregate having more than 10 pct passing the No. 100 sieve has been used successfully in concrete shields.

When heavy aggregates are processed for prepacked concrete, the coarse aggregate should be larger than ⅜ or ½ in. To facilitate intrusion in grouting, aggregates should also be washed free of fine dust before being packed in the forms. Heavy grout sand should be finer than the No. 16 sieve and should have a fineness modulus of 1.0 to 1.5—the heavier the sand, the finer it must be to stay in suspension. Grinding in a rod or ball mill may be required to produce grout sand and this is expensive. More economical sources of heavy grout sand may be magnetite concentrates or the product from a Humphrey spiral mill.

When selecting a particular source of heavy aggregate, the engineer must watch out for extraneous materials that may impair the strength of the concrete or reduce the average density of the ore. Gangue is usually not objectionable if it is structurally sound and relatively inert. Some materials are objectionable because they are weak, light in density, or unstable. Certain siliceous compounds and minerals, such as opal and chalcedony, react chemically with alkalis contained in portland cement. Barite from one mine was not suitable for use in concrete because it contained too much opal. On the other hand, silica occurring in normal amounts in iron ore is not reactive. The various mineral types occurring in the aggregate should be compatible with each other and with the behavior of other ingredients in the concrete during expansions and contractions. Such length changes can occur upon

Table I. Compositions of Several Types of High-Density Concrete

Placement	Weight, Lb Per Cu Ft	Material Cost, $ Per Cu Ft	Initial Composition, Lb Per Cu Ft: Portland Cement	Fine Aggregate	Coarse Aggregate	Mix Water	Water Retain at 85°C, Lb Per Cu Ft
Prepacked	346	18.40	20.6	Magnetite (44)	Steel (270)	11.3	3.5
Conventional	300	12.05	24.1	Ferrophosphorus (92)	Ferrophosphorus (171)	12.7	3.6
Prepacked	263	11.20	22.2	Limonite (28)	Limonite (60) steel (140)	12.2	13.0
Conventional	232	2.20	24.3	Magnetite (86)	Magnetite (110)	11.5	5.7
Prepacked	227	3.30	10.3	Barite (29)	Barite (168)	10.5	2.9
Conventional	219	2.10	24.9	Hydrogenous iron (82)	Hydrogenous iron (100)	12.0	9.2
Conventional	185	3.10	31.3	Limonite (62)	Limonite (76)	15.4	17.1
Conventional	184	0.50	31.3	Local sand (50)	Gravel (61)	11.5	4.7

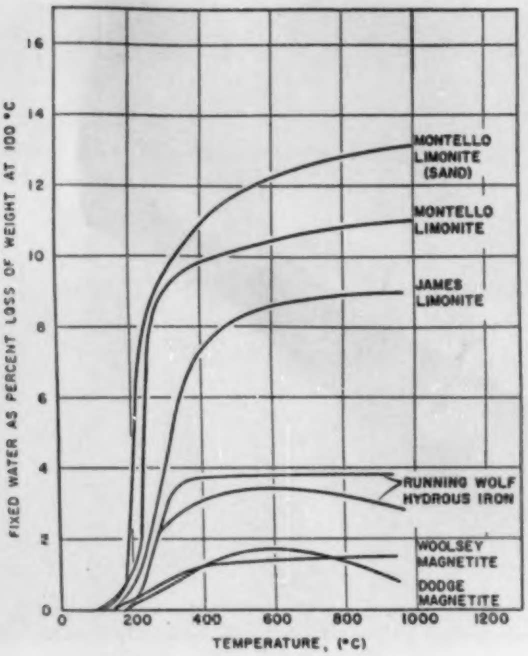


Fig. 1—Fixed water contents of heavy aggregates.

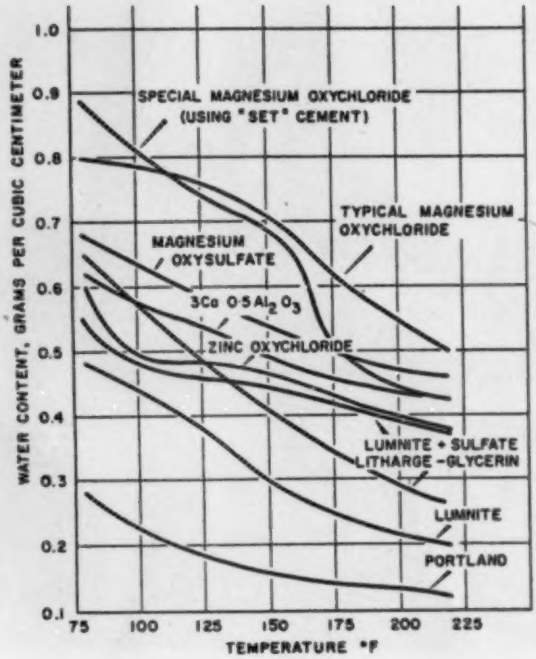


Fig. 2—Water contents of various cements.

wetting and drying and during thermal cycling. The effects of high temperature and nuclear radiation on shield materials must be evaluated also.

Chemical Composition: In most cases, the exact chemical composition of heavy aggregate is not critical as long as the required density is met. Whereas the sulfur and phosphorus contents of iron ore are important in production of pig iron and steel, normal contents of sulfur and phosphorus are not objectionable for heavy aggregates. To obtain high density, high grade ore is required, which means that the amounts of other mineral compounds should be low. The barium sulfate content of barite should be greater than 90 pct, while the iron content of magnetite and limonite should be greater than 60 and 55 pct, respectively. These figures are not absolute minimums, since local procurement and economy may justify using lower values.

For some shielding applications it is necessary to limit the content of certain elements if they become very radioactive in a neutron field. Concrete aggregates used in removable shields and step plugs are subjected to such limitations. Barite is sometimes used instead of magnetite to minimize this problem. Shown in Table III are a number of elements having high gamma activities; those having a long half life and large thermal cross section are especially objectionable.[4] Sulfur, phosphorus, and silicon do not appear in this table, since they are beta producers.

Table IV summarizes results of spectrochemical analyses made on several types of heavy aggregates. These data indicate the wide range of trace elements that may be present in heavy ores. As far as induced radioactivity goes, iron with its half life of 47 days is about as bad an offender as any of these trace elements. If it were not for this characteristic, iron would be an excellent shield material for most situations.

Radiation Attenuation and Absorption: Presented in Table V are representative values of absorption factors for several types of heavy aggregate.[4,5] The actual absorption factor for a given material is equal to the corresponding value given in Table V mul-

Table II. Physical Properties and Cost Data for Heavy Aggregates

Heavy Aggregates	Source	Primary Identification	Specific Gravity (SSD) Coarse Pieces	Specific Gravity (SSD) Fine Sand	Percent by Weight Iron	Percent by Weight Fixed Water	Dollars Per Short Ton F.O.B. Source	Dollars Per Short Ton Processed at Job†
Limonite-goethite	Michigan	$2Fe_2O_3 \cdot 3H_2O$	3.75	3.80	58	9	7	40
	Utah	$Fe_2O_3 \cdot H_2O$	3.45	3.70	55	11	20	40
Magnetite	Nevada	Fe_3O_4, etc.	4.62	4.68	64	1	9	20
Magnetite	Montana	Hydrous iron*	4.30	4.34	60	2 to 5	7	18
Barite	Tennessee	92 pct $BaSO_4$	4.20	4.24	1 to 10	0	18	22 to 30
Barite	Nevada	90 pct $BaSO_4$	4.28	4.31	1	0	19	30 to 40
Ferrophosphorus	Tennessee and Missouri	Fe_3P, Fe_2P, FeP	6.30	6.28	70	0	80	90
Steel aggregate	Punchings	Sheared bars	7.78	—	99	0	120	130
Steel shot	Chilled	SAE Standard	—	7.50	98	0	120	130

These aggregates are representative of some of the best which can be obtained commerically.
* This ore is primarily magnetite, with some hematite (Fe_2O_3) and limonite.
† Grout sand will cost about $50, $40, and $30 per ton for limonite, barite, and magnetite, respectively. Values for processed aggregates include $10 per ton for freight.

Table III. Aggregate Constituents with High Gamma Activities

Elements	Thermal Absorption Cross Sections (σ a) Barns Per Atom	Half* Life	Gamma Energy* (E) in Mev
Na	0.45	15.0 h	2.76
Mg	0.05	9.6 m	1.0
Al	0.22	2.3 m	1.8
V	4.5	3.8 m	1.4
Cr	2.5	26.0 d	1.3
Mn	13.0	2.6 h	2.1
Fe	2.56	45.0 d	1.3
Co	36.0	5.2 y	1.3
Cu	3.6	12.8 h	1.3
		4.3 m	1.3
Zn	0.9	{ 250.0 d	{ 1.2
		14.0 h	0.9
Ba	1.58	85.0 m	1.0

* "Worst" activation products. In most cases the saturated activity may be taken as $\phi \sigma N$ where ϕ = neutron flux, σ = microscopic cross section of material, and N = atoms per cubic centimeter of original material. A more complete tabulation is given in Ref. 4.

Table IV. Spectrochemical Analyses of Heavy Aggregates

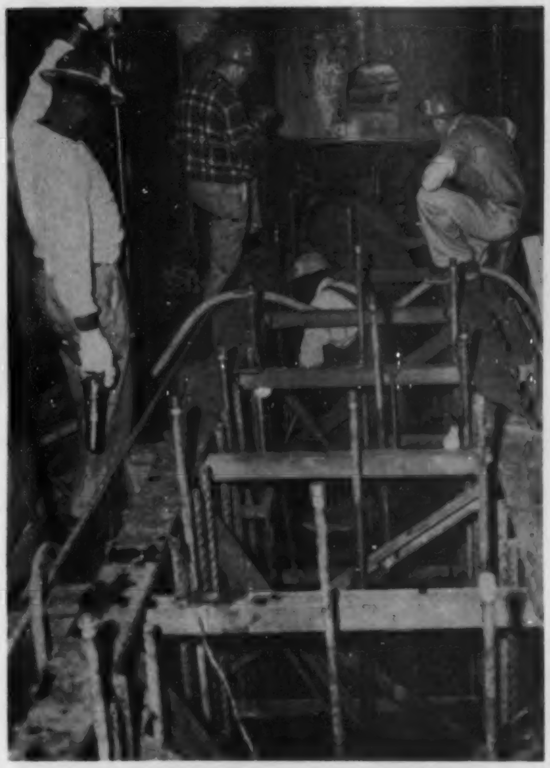
Element	Rossi Barite	Montello Limonite	Dodge Magnetite	Silver-bow Ferro-phosphorus	Portland Cement
Ag		*	—	—	—
Al	S	M	M	M	S
As		M	—	—	—
B		*	T	—	T
Ba		M	—	—	M
Bi	S	—	—	—	—
C		*	*	*	*
Ca	T-M	M	T-M	—	S
Co		T	—	—	—
Cr		T	T	S	T
Cu	T	M	T-M	M	T
Fe	M	S	S	S	M-S
K		T-M	—		M
Li		T	—	—	T-M
Mg	M	M	M	T	M
Mn	T-M	M	M	M	M
Mo		T	—	—	—
Na		T	T		M
Ni		—	T	M	T
P		—	—	S	—
Pb		M	—	—	M
Si	M-S	M	M	M-S	S
Sr	M-S	T	—	M	
Ti	T	T	T	S	
Tl		—	—	—	M
V		T	—	M-S	T
Zn		M	—	—	—

S = strong; M = moderate; T = trace; * = interference. Dash means element was not detected. Approximate concentration: greater than 1 pct; 1 pct to 0.01 pct; and less than 0.01 pct.

Table V. Average Values of Absorption Factors for Concrete Aggregates

Type	Composition	Specific Gravity G Per Cm³	Absorption (Cm² Per G) Fast Neutrons*	Absorption (Cm² Per G) Gamma Rays (3 Mev)
Alumina	Al_2O_3	3.6	0.0330	0.0365
Barite	$BaSO_4$	4.3	0.0236	0.0363
Ferrophosphorus	Fe_xP	6.4	0.0230	0.0359
Goethite†	$Fe_2O_3 \cdot H_2O$	3.7	0.0372	0.0362
Iron	Fe	7.8	0.0214	0.0359
Lead	Pb	11.3	0.0103	0.0413
Lime	CaO	3.1	0.0286	0.0372
Limestone	$CaCO_3$	2.7	0.0327	0.0368
Marble	$CaCO_3$	2.7	0.0327	0.0368
Magnetite	Fe_3O_4	4.6	0.0258	0.0359
Quartz	SiO_2	2.6	0.0328	0.0362
Water	H_2O	1.0	0.10 to 0.134	0.0396

* Computed values using relationship $0.0852\ A^{-1/3}$ cm²/g for elements having atomic weight A, except for measured values given in Ref. 5.
† Limonite having 10 pct water by weight.

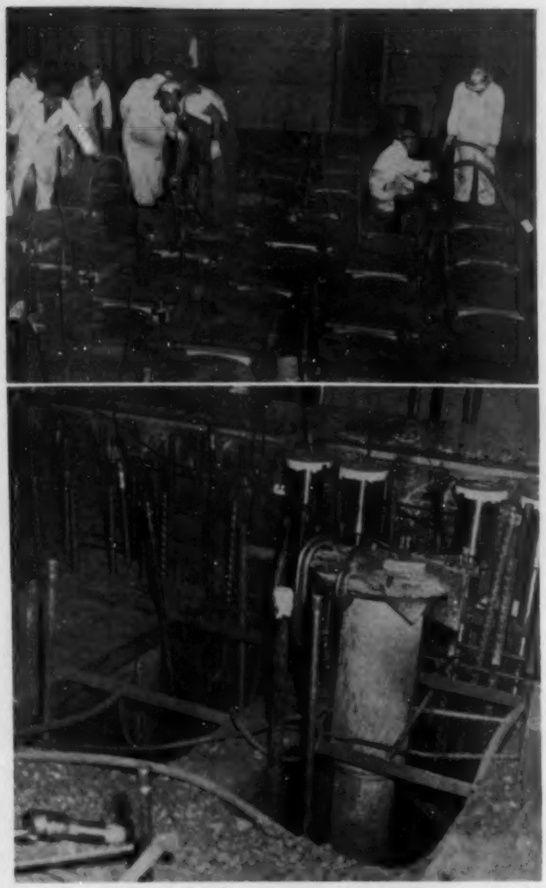


Aggregate is moved into place with pneumatic tampers and compacted to density predetermined by weight of aggregate placed and volume occupied in forms. Note ¾-in. pipes through which grout will later be injected.

tiplied by the specific gravity. To minimize the thickness of a gamma shielding wall, therefore, it is necessary to use the densest aggregate available.

High density is not the only factor to consider when selecting aggregate for a neutron shield. To increase the hydrogen content of a concrete shield, as required to slow down fast neutrons, hydrous-iron ore is sometimes added to the mix. Limonite or goethite having 10 to 12 pct water of crystallization at about 85°C and a specific gravity more than 3.5 may be used in combination with magnetite or steel punchings. In some designs, hydrous-iron having a water content of 7 or 4 pct is of interest if the specific gravity is about 3.7 or 4.2, respectively. Fig. 1 shows the results of heating tests performed on several types of iron ore. It will be observed that limonite and goethite are reliable sources of hydrogen as long as shield temperatures do not exceed 200°C.

Cements for High-Density Concrete: Cements for high-density concrete are chosen on the basis of strength, water content, and density. Special cements having high water content or high density have been developed recently for use in shielding structures, but to date they have not been used extensively in major structures. Portland cement is normally used, since its behavior under a wide range of conditions is well known. Then too, shields built with portland cement have been found to attenuate pile neutrons adequately. Fig. 2 summarizes data obtained at Battelle Memorial Institute for several types of cement.[6, 7] Of the special cements, magnesium oxychloride (MO) appears most promising



TOP: Heavy grout being injected into aggregate in top shield. Layer of conventionally mixed heavy aggregate will be placed on top, after which shield will be completed by covering it with a steel sheet. BOTTOM: Aggregate is placed in top shield of reactor by discharging it from bucket. In lower parts of forms, it was dropped through elephant-trunk to reduce breakage and segregation and to prevent displacement of inserts.

when used with inert aggregate such as ferrophosphorus. When iron shot is used with MO cement, rusting occurs which impairs the strength of the concrete.

Economy: In selecting a source of heavy aggregate for a particular shield, transportation costs must be considered, since they may be greater than the initial cost of the heavy ore. In general, complete cost study of the shielding and associated reactor equipment must be performed to determine whether or not it is more economical to use heavy aggregates of local sand and gravel in the reactor shields. The availability of a suitable source of heavy aggregate near the construction site is often a deciding factor in such evaluations. In some cases, premium prices can be paid in order to obtain aggregates of high density and of uniform quality. Certain mining companies are in a good position to produce premium aggregates during their normal mining and processing operations, as they already have screens, sink floats, or other equipment that can be used to separate the dense, lump ore from the mine run material. Others may have to resort to selective mining procedures to meet density requirements. Small mines containing dense ore may prove productive. A

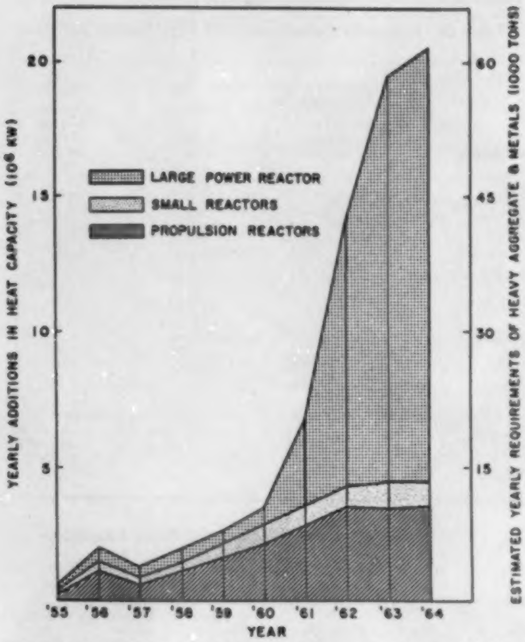


Fig. 3—The future market for heavy aggregates in shield construction.

knowledge of the physical and nuclear requirements of heavy aggregates for reactor shields will assist the mining engineer in locating suitable sources and in processing heavy aggregates.

Future Market for Heavy Aggregates: The question is often asked, "What is the future market for heavy aggregate? The answer is related to the future development and utilization of nuclear fuels for producing useful power. Depending upon the size of the reactor plant, several hundred or several thousand tons of heavy aggregate may be required per reactor. For large nuclear power plants, about 3 tons of heavy aggregate are required per kilowatt of heat capacity. Fig. 3 presents the results of a growth survey of the atomic industry, 1955 to 1965, made by the Atomic Industrial Forum Inc.[8] Based on these power plant capacity data, the scale on the right side of Fig. 3 gives the corresponding tonnages of heavy aggregate required for constructing radiation shields, assuming that it is economical and expedient to use heavy aggregates and not conventional sand and gravel. When compared to the millions of tons of iron ore produced yearly in the U. S., the amount of heavy ore required for reactor shields appears small. However, there is a definite future need for heavy aggregate in shield construction—a market that will undoubtedly be met by the cooperative effort of the mining industry.

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The Daniel C. Jackling Lecture

An annual invitation address by an outstanding man in mining, geology, or geophysics who has contributed significantly to the progress of technology in these fields.

THE LECTURER

J. L. Gillson

THE PRESENTATION

by Ian Campbell

IT is a somewhat curious circumstance that the newest of the Institute's several awards should be conferred in the oldest of our several professional fields—for there is little question that geology and mining have antedated metallurgy and petroleum. Perhaps so did geophysics. After all, one geophysical instrument, the magnetic compass, has been successfully employed for many centuries.

Young in years the Jackling Award may be, but in distinction—whether in terms of the title it bears or in terms of the first three medalists (Reno Sales, E. D. Gardner, and the late Father Macelwane)—the Jackling Award is already one of the ranking awards of the Institute. The name of the 1957 medalist will bring added luster to an already illustrious roll.

J. L. Gillson was born and brought up in Evanston, Ill., in an area characterized by singularly flat and uninspiring topography, and devoid of ore deposits and even of bedrock—a most unlikely environment from which to expect a future Jackling medalist to emerge! On graduating from high school he enrolled as a chemistry major at Northwestern University. At the end of his freshman year his scholastic prowess had won him a prize of two chemistry books. But these went unread, for about this time he came under the spell of U. S. Grant, that distinguished and enthusiastic geologist who for many years was head of Northwestern's geology department. From thence forward Joe was a dedicated geologist. After a Navy interlude in World War I, he went to MIT for graduate work, substituted for the late Professor Palache for one year at Harvard in mineralogy, received his doctorate at MIT and stayed on as a member of the MIT faculty, where the geology department was headed by that great dean of all economic geologists, Waldemar Lindgren. In 1926 Joe spent a summer looking into barite deposits for the du Pont Co., and since 1928 he has been du Pont's chief geologist.

Do men who lead such active lives in our exploration organizations generally have permission to publish their observations? Do they generally find time to publish, even if they have permission? Alas, no. But in Joe Gillson's case, yes. His bibliography runs to well over two score papers, including one of the very first papers in this country on the applications of petrography to problems of Portland cement. He has written on such topics as the origin of talc and the genesis of ilmenite, fluorspar, and alkaline rocks. Each year for a number of years his annual reviews of industrial minerals in the *Mining Congress Journal* have been eagerly awaited.

Do men who do so much to advance their science have anything left to give to the advancement of their profession? In Joe Gillson's case, yes. He has been a vice president of the Mineralogical Society of America and has been active in the councils of the Society of Economic Geology, particularly in their research programs. This year he is president of the American Geological Institute, currently perhaps the most challenging post to which a geologist may be elected. His contributions to AIME scarcely need documentation, so I shall mention only three—his chairmanship of the Committee on Democratization of the Institute, a committee whose work and recommendations brought a new and hopeful leaven to AIME at a time when this was sorely needed; his chairmanship, a few years ago, of the Industrial Minerals Division; and his current place on the Board of Directors as Vice President of the Institute.

Such a catalogue of contributions and achievement, even as condensed as I have had to make it, certainly merits the Jackling Award. Yet, implicit although not often expressed in the conferring of most awards is the hope that besides recognizing a distinguished career, it will provide stimulus for further effort. In the present instance, such an expectation is already well on the way to fulfillment. Only recently Joe Gillson has undertaken the editorship of a new and greatly revised edition of the Institute's Seeley Mudd volume, *Industrial Minerals and Rocks.*

And so, Mr. Chairman, it is with pleasure and enthusiasm that I present Dr. J. L. Gillson for the 1957 Jackling Award.

The Transactions papers appearing in MINING ENGINEERING during 1957 will appear in AIME Transactions Volume 208, and may be permanently referenced to that Volume.

The 1957 Jackling Lecture

A Geologist Looks at Industrial Minerals

by Joseph L. Gillson

YOUR speaker has long sought an opportunity to review the many differences between the subject matter called *economic geology* and the duties of a practicing economic geologist. As the subject was taught in my student days, professors teaching courses in economic geology paid little attention to what we now call *industrial minerals*. Certainly they were not concerned with problems involving production and marketing, but only with the origin of such mineral deposits as the Stassfurt potash deposits; with other evaporites, such as salt, gypsum, and Chilean nitrate; with the possible modes of formation of sulfur in salt domes; and the causes of asbestiform mineralization. Of course, much time and thought was given to the mineral identification and sequence of deposition of the minerals in pegmatites. The fact that such deposits actually produced commercial feldspar, mica, beryl, and lithium minerals for sale in industry was of minor importance.

These observations lead us to pause to inquire, perhaps facetiously, what is and what is not to be included in the science of economic geology?

In Professor Waldemar Lindgren's courses in the early 1920's, the subject matter of economic geology was limited almost exclusively to a study of ores from the principal metal mines of the world, mostly by polished section methods. The ultimate goal of our studies was to work out the paragenesis (i.e., the mineral sequence of deposition) and nothing else seemed to matter very much. As an aside, it may be mentioned that in that era, the most profitable consulting work open to economic geologists was acting as an expert witness in a court case, testifying as to what was, and what was not, a *vein*.

As a long-time reader of the publication *Economic Geology* (my bound volumes go back to 1913) and as a Councilor of the Society for two terms, and once its Vice-President, I have sought for definition of the science of economic geology from noting the subject matter of articles published in that journal. We might note, parenthetically, that the Council of the Society has no authority over, nor any direction of, the editorial policy of the journal. With a few outstanding exceptions, the articles accepted for publication have been concerned primarily with descriptions of the general geology and the genesis of mineral deposits and studies of ore minerals and ore solutions. Only about 15 pct of the leading articles have been concerned with nonmetallics, and this 15 pct includes many articles on ground water. We will inquire later in this analysis whether ground water is an industrial mineral. It is, of course, unnecessary to mention that, within the limitations of the subject matter, the articles are excellent.

I have thumbed through volumes of the journal, seeking in vain for a discussion of costs of production; or of preparation of concentrates to meet specifications for particular markets; or of the importance —to the overall *economics*—of location, routes and means of transport, political control, taxes, and percentage depletion. These subjects, apparently, are not the concern of the economic geologist. If management has to hire others who can look into those questions, it is no wonder that the fee or salary paid to the geologist is moderate.

Since I studied my economic geology in ore deposits under Professor Lindgren, you may ask why and how I became interested in the nonmetallic field. One day, while on the staff at Massachsetts Institute of Technology with the title of Assistant Professor of Mineralogy and Petrology, I asked Professor Lindgren if I might teach a course in nonmetallics. His favorable reply certainly made a turning point in my career. During the next several years I had to make the attempt to keep one jump ahead of some very bright students, in preparing lectures on the 50 subjects in the broad field of nonmetallics.

In 1926 an executive in du Pont Co. turned to his Alma Mater to find someone to examine barytes deposits in the South. Because of my then vast (?) ex-

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TP 4365H. Manuscript, March 20, 1957. New Orleans Meeting, February 1957.

perience in the field of industrial minerals, Professor Lindgren turned the letter over to me, and that started an association which has now lasted over 30 years. Summer work examining barytes deposits in the South and reviewing sulfur production on the Gulf Coast led to full-time employment beginning in 1928. In about 1929 du Pont invested in the titanium pigment business, and this started me on a worldwide study of ilmenite deposits. In 1932 du Pont began making fluorinated hydrocarbons, and this added the second mineral field to which I have devoted a great deal of time—fluorspar.

Credit for my broad interest in industrial minerals must also go to some of the oldtimers in the Industrial Minerals Division of the AIME, especially Professor Benjamin Miller of Lehigh at the time he was chairman of the Division, and Jack Thoenen, Frank Hess, Oliver Ralston, and Oliver Bowles of the U. S. Bureau of Mines, as well as to many others.

Many years of professional work for a very dollar-minded employer led me to the conclusion that paragensis of ore minerals and the theory of origin of mineral deposits are only a part of the actual problems connected with the occurrence, production, beneficiation, and marketing of industrial minerals. However, not to discourage those who have an enthusiastic interest in the technical problems of geology from entering the field of industrial minerals, one example can be cited to show that in such professional work there is still room for applying geological knowledge and theory. This example is the study of the fluorspar deposits at Encantada and Buena Vista in northern Coahuila, Mexico, which were discovered in 1951. Early work by Mexican *gambosinos* in 1952, which opened up the most obvious and most accessible pods of ore, indicated an apparent lack of any depth or continuity to the deposits, which are of the bedded replacement type. After drilling 50 dry holes into the underlying limestone, one American geologist working in the area came to the conclusion that the fluorspar in that district is of very recent age and had formed only at the present surface. He so expressed himself in a paper presented before a meeting of this Institute in El Paso. My studies satisfied me that the fluorspar deposits were mesothermal, and probably Miocene in age, and that the replacement was reasonably continuous within the single horizon of the thin Del Rio shale. The isolated and discontinuous pockets in the underlying limestone were found where the fluorine-bearing solutions had leaked downward and locally had filled cracks and old solution cavities in the Edwards limestone, which had been weathered and leached before Del Rio time. There are many hectares in the ore-bearing zone, where the soft and easily eroded Del Rio shale, with its fairly continuous bed of spar, had been eroded off the massive Edwards limestone. Hence all that remained in these areas of the original fluorspar deposition was found in these isolated and discontinuous pockets in the old solution cavities. I sought areas where the geological section was complete from the Edwards up past the Del Rio and the overlying Buda, and into the upper Cretaceous Eagle Ford, and claims were acquired in some of these areas. By the end of 1956 many of the neighboring Mexican workings had gone into the side hill and continued within the Del Rio shale until they connected through with workings on the other side of the same hill, proving the correctness and interpretation of age and genesis.

My professional work has taken me to a number of foreign countries and has taught the necessity of becoming familiar with the politics and economics of a foreign land. I have always found these subjects interesting, sometimes amusing, and often frustrating.

I had to learn a great deal about the political situation in India, when du Pont began in 1930 to depend entirely on that country for its supplies of ilmenite. There the mineral occurs as a marine placer on beaches along the Malabar coast in what was then the native state of Travancore. This was then ruled by a young Maharajah with a great deal of pomp and ceremony and parading of elephants and sacred cows. Before the second World War, however, the English were still in a strong, although supervisory position, and an English company could operate with a minimum of interference. During the second World War, the English were forced to put a number of the local politicians in jail because of pro-Japanese activities. These gentlemen gained their freedom in 1945 and were full of energy and ideas, but woefully short of practical experience in government. They nationalized the industry, expelled the English companies, and put their political henchmen in control with you-know-what results. I attended a meeting in June 1948 in the hot and stuffy Room of State in the city of Trivandrum, capital of Travancore, and attempted to explain to the ministers that if their shipments of ilmenite became undependable, the U. S. consumers would turn to other sources of supply. The big deposit of ilmenite-hematite in anorthosite, at Allard Lake in eastern Quebec, was then under development by the Quebec Iron and Titanium Co., and the dredging operation on the middle Pleistocene sand spit, called Trail Ridge, in north central Florida, was just going into production. The only reaction to my pleas was that my arguments were just sales talk. Now, eight years later, titanium mineral production in the U. S. and Canada has grown to huge figures, while the Indian production from its rich beaches, which could be operated very cheaply, has declined. Who has suffered? It possibly is unnecessary to include the comment that we taxpayers in the U. S. have to support loans and grants to India to develop their industries.

I am now just returned from Brazil, a country with tremendous resources of minerals. While there I had two half days of field work, the rest of the time being devoted to studying and inquiring into the possibilities of an American company trying to produce minerals in Brazil.

With this philosophical introduction, let us turn now to a review of the industrial minerals and assemble some facts and figures that may permit us to understand something about the very magnitude of the whole field and to learn some interesting bits of information that have made the subject so stimulating.

There are about 50 principal industrial mineral subjects covered in the AIME volume *Industrial Minerals and Rocks,* of which a new edition is now in preparation. The dollar value of these numerous products (listed except for cement and lime as crude or only partially manufactured products) is shown here in Table I, for both 1952 and 1954, together with several metals of large volume. It was necessary to include 1952 for comparison, since 1954 was a poor year for iron, lead, and zinc, and the comparison of metals and nonmetals for 1954 only would not have been typical. Note that uranium

ores are not included in the figures for metals. Note also the great increase in the value of the production of industrial minerals from 1952 to 1954.

These figures show that in 1954, excluding fuels, the largest single unit in the mining industry—covering just crude ores and rocks—was crushed stone, and these figures for stone did not include the stone used for the manufacture of lime and cement. Sand and gravel exceeded copper in value in 1954, and sulfur, lime and clay products exceeded $100 million in 1954, whereas lead and zinc are the only other metal industries to exceed that figure in the good year of 1952.

Of course, the production of uranium ores is very large, and probably now exceeds a value of $500 million, and the omission of figures for uranium reduces the gross of the metal industry. Some may question also whether cement belongs in the tabulation, since it is a manufactured product, as is lime, and these products inflate the gross of the industrial minerals industry. However, the degree of manufacture for lime and cement is no greater than the amount of *manufacture* accomplished in producing lead, copper and zinc pigs and spelter from crude ores. The gross figures used for those metals are obtained by multiplying the pounds of recoverable metal in the ores by the average annual price of the metal produced and sold.

The subject of sand and gravel and crushed stone and aggregates has always been a challenging one to me because of the very magnitude of the physical volume, but it has always given me the most trouble in describing the production and marketing aspects to an audience in a manner that can arouse and hold its interest. The editors of the *Mining Congress Journal* have extended the privilege to me for the last several years of writing the annual review of industrial minerals (excluding some subjects) which is published in their February number. I know a number of the producers of sand and gravel and of crushed stone personally, particularly in the East and Southeast, and I can assure you that many of these companies are *big business*. Questions directed to their managements for news items to include in the annual review elicits such replies as "Oh, we bought six new barges, or perhaps 10 new Euclid trucks." They feel pleased when they can report that they stayed *in the black* in spite of steadily rising labor and equipment costs, because the selling price of their products has risen very little, if at all, during the last few years.

To make such news items interesting, I have turned to the pages of the *Engineering News Record*

Table I. Mineral Production in Continental U. S. Total Value in Thousands of Dollars

Metals	1952	1954
Iron ore	$590,346	$525,416
Copper	447,882	492,927
Lead	125,631	89,165
Zinc	222,981	102,180
Total	$1,611,000	$1,506,000
Nonmetals		
Sand and gravel	344,569	496,672
Crushed stone	461,064	602,037
Cement	637,746	763,413
Clay	122,385	124,856
Lime	94,795	101,273
Phosphate	68,120	86,669
Potash	53,754	71,819
Sulfur	110,925	142,014
Total	$2,156,000	$2,718,000

Figures supplied by U. S. Bureau of Mines.

for statistics on the number of big dams building, the number of major bridges under construction, and the volume of public and private construction, since in these figures we can measure what those hard-working, cost-paring quarry and pit operators have been doing during the year. The President's highway construction bill of 1956 was certainly one of the major acts in American history which will stimulate the business in the pits and quarries. It is estimated that in 1957 $5.9 billion will be spent on roads of all types and by all agencies, a figure which compares with $4.9 billion in 1956 and $4.3 billion in 1955. Early in 1956 there were 69 major dam, lock, levee and flood control projects under construction, and later in the year this volume was increased by authorization of such major projects as the big dams at Glen Canyon, Flaming Gorge, and Priest Rapids. Ten major highway bridges were under construction and three were finished in 1956. The Indiana and Kansas turnpikes were finished, and every major city was reaming out traffic bottlenecks. Many major water development projects were being pushed, such as New York City's 44-mile tunnel to tap the Delaware River, and Baltimore's Petapsco and Susquehanna projects. Grandest of all, California's $1.2 billion Feather River project was finally getting off the ground.

It has seemed to me that reminding the American public—many segments of which see only the little local job in their own communities of widening Main Street—of the tremendous surge of vital energy on the American scene gives a better picture of the activities of our pit and quarry industry than a mere listing of new trucks bought, dredges building, or even of tons of products shipped.

The clay products industry is another difficult one, because it includes the low valued products of large volume, such as sewer pipe, tile, and brick. These are based on neighborhood clay pits, and most are manufactured by small local companies. The industry includes also refractory, ball and china clays requiring strict specifications in their preparation. Many facets of this industry are exceedingly technical and require large resources in capital and skilled man power. The science of geology and mineralogy of the clays and clay deposits is certainly one of the most scholarly of the entire nonmetallic field and requires the most specialization.

The industrial mineral subjects of intermediate volume and dollar volume include sulfur, the fertilizer materials, phosphate, potash, nitrate (the latter is mainly a branch of the chemical industry), borax and borates, salt, gypsum, ilmenite, barytes, fluorspar, and asbestos. The geology and production problems of this list are too diverse to allow tabulation and description here, but a few outstanding developments may be mentioned.

Within a few miles of New Orleans are some of the operations for production of that most basic of chemical raw materials—sulfur. We will have an opportunity here today to hear from a vice president of one of the producing companies, and some of you may visit a plant on a field trip later in the week. Twelve miles out in the ocean from the shore of the Mississippi delta a big salt dome has been found recently by geophysical exploration. Drilling has shown that it contains a major sulfur deposit— most welcome news to those who remember the 1952 shortage all too vividly. Another dome is on land, if you can call a swamp 2 ft above tide *land*. You who know some chemical engineering can appreciate the

marvelous accomplishment of the engineers when they learned to steam the sulfur out of salt domes with superheated salt water. Now that the occurrence of sulfur in salt domes is fairly well understood, exploration and development for sulfur is in the hand of the geophysicist, the engineer skilled in oil well drilling, and the chemical engineer.

We can look briefly, moreover, at some other industrial minerals in the list of those of intermediate volume, to note some outstanding recent developments and achievements. The common borate minerals, after a century in the kitchen and laundry, have suddenly blossomed as the raw materials for a whole new field of chemical development—that of the boranes. Three major chemical companies have established very large new laboratories in which extensive research programs in this new field are being undertaken. To quote *Business Week* for Oct. 20, 1956, boron compounds are poised for a burst into exciting new uses in glass, glazes, flame-proofing agents, enamels, adhesives, resins, abrasives, and most glamorous of all, rocket fuels.

Because of my long association with the fluorspar industry, it is natural that I turn to it as an example of an industrial mineral, the growth of which comes from the activities of research chemists and metallurgists. Fluorspar is a little known work horse. For every ton of steel produced by the basic open hearth process, 6 lb of fluorspar are required, and for every ton of aluminum, 120 lb. However, it is the chemical industry that is finding the largest new uses for this mineral. This room in which we are gathered, like hundreds of thousands of other rooms in the U. S., is air conditioned—how? By using a fluorine compound. When a liquid evaporates, it absorbs heat (i.e., cools its surroundings) and the resultant gas can be reliquified by compression. A refrigerant is a chemical that boils, that is evaporated, at a temperature convenient to the level desired—moderate for air conditioning, low for deep freezing—and can also be reliquified at modest pressures. It must be safe to handle—nontoxic and nonflammable. The only chemicals to find acceptance in these limited specifications are fluorinated hydrocarbons, of which the most widely used is dichlor-difluor methane ($C\,Cl_2F_2$). Now, except for the large commercial ice plants, which still use ammonia as the refrigerant, and the gas refrigerators used where electricity is not available, such as Electrolux, which function because of the absorption of hydrogen in ammonia with absorption of heat, every air conditioner and refrigerator uses these fluorinated hydrocarbons.

This year 150 to 200 million *aerosol* bombs will be used for insect sprays (bug bombs), fire extinguishers, air fresheners, and shaving cream. The largest number of all will be used for lacquer hair sprays. An aerosol bomb is a container of compressed gas that dispenses a spray carrying the lacquer or the insecticide. The gas is fluorinated hydrocarbon, used because it has a low vapor pressure and is nonflammable and nontoxic. A half pound of this gas can be compressed into a beer can, whereas a half pound of some other inert gas like nitrogen or carbon dioxide would require a true bomb with a thick steel shell to hold the high vapor pressure.

Because of the wide acceptance of these aerosols, and the rapid growth of the air conditioning business, the curve of fluorspar consumption is rising, helped, of course, by the growth of the steel industry and by the still very rapid growth of aluminum. Moreover, chemists from a dozen or more major chemical companies are working in the field of fluorine chemicals, and all are optimistic about the future of their new compounds. Hence the present consumption of about 550,000 tons of fluorspar of all grades in this country is expected to grow to 1 million tons by 1965, and probably sooner. Many American producers have been grouching because the price has been held down and their market restricted because of the flush of imports, particularly from Mexico, and have sought relief from the U. S. Tariff Commission. In my opinion, it is not the producers who should be worrying about where they are going to sell their fluorspar, but rather the consumer as to where he will obtain his supplies.

Another large consumer of industrial minerals is the glass industry, which sold $17 billion of glass in 1956. Corning Glass Co. has stated that 75 pct of its revenue in 1955 came from products not known in 1940. The automobile industry used 5000 acres of flat glass in 1955, and there has been much speculation by outsiders as to how the wrap-around windshields are made. Three firms make them. The windshield starts out as two pieces of polished plate glass, placed one on top of the other on a form, which is carried through an oven, where the glass plates are preferentially heated at some points, causing them to sag into the desired shape. A sheet of vinyl plastic is placed between the bent plates and the elements of the sandwich are bonded together.

A glass called *dusk light* admits only 30 pct of outside glare and is proposed for building walls, while a glass with a thin film of a metal oxide that conducts electricity is used as a heating unit. By the addition of phosphors, a window can be made to glow in the dark.

The familiar Thermopane, which consists of two pieces of glass with an air space between to serve as a single unit storm window, was formerly bonded or sealed with metal. The manufacturer now has a glass solder that reduces the cost of the final product, thus increasing its market. One of the most interesting examples of a special glass is in the television field. A shadow mask for color television has 200,000 carefully spaced and tapered holes. These holes channel the electrons from the *gun* into the face plate of the color set, thus exciting 600,000 red, blue, and green phosphor dots.

Foam glass that can be fitted around the most intricate piping has been a boon to the heating and piping industry. The user can simply scrape out the center of a glass brick which looks like pumice, until it fits around any odd-shaped part. The glass brick is moisture-proof and rodent-proof.

Another segment of the industrial mineral field in which aggressive development has taken place is the gypsum industry. There are ten companies operating 45 calcining and wall board plants. Gypsum deposits have been developed recently in Indiana, Michigan, and Nevada and on San Marcos Island on the Lower California peninsula. There has also been a large-scale expansion of operations in Nova Scotia. The water transportation of gypsum along the east and west coasts, and in the Great Lakes, requires a fleet of special boats that has put the gypsum companies in the shipping business. Equipment for loading and unloading of these big boats has required tremendous installations of materials-handling equipment.

In the building industry the activities of those making light-weight aggregates from perlite, slag,

and expanded shale have been most aggressive. Although there has been nothing outstandingly noteworthy about these products or the industry during the past year or two, the steady growth of the industry shows widespread acceptance of these products. This growth has given increased business to producers of the raw materials, and the search for suitable deposits of perlite and shale has given employment to a number of geologists.

Still another industry in which the producing members have been making intense efforts to increase capacity and expand their reserves is the asbestos industry. Of course, except for active but small-scale developments in Arizona, the major developments have been in Canada, South Africa, and Rhodesia. In the Eastern Townships of Quebec are three areas called Asbestos, Thetford Mines, and East Broughton. At Asbestos, the Johns Manville Co. already has the largest building in Canada to house its mill and dressing plant, but feeling crowded, the company has decided to expand the building to give an additional 75,000 ft of floor space, which will increase capacity to 16 production lines delivering 625,000 tons of fiber annually. Forty miles away, at Thetford Mines, National Gypsum Co. is expanding its plants and quarries, but the most spectacular development is that by Lake Asbestos of Quebec Ltd., a subsidiary of American Smelting and Refining Co. To open a quarry in a big asbestos deposit under Black Lake, the company is spending $32 million to remove 35 to 40 million cu yd of silt, clay, and sand from the bottom of the lake, which will be drained. My employers have been operating two suction dredges at Trail Ridge, Fla., to handle ilmenite sand at the rate of 850 tph, and we have considered these dredges to be large, since the suction pump has a 22-in. intake and is powered by a 900-hp motor. At Thetford the suction dredge has a 34-in. suction line, and the pump has a 6000-hp motor! Operations are expected to start in 1958. Other Canadian asbestos developments are in the Ottawa Valley; in Ontario between Kirkland Lake and Cochrane; and in northern British Columbia, where Cassiar Asbestos Corp. is working on a mountain in a very remote and difficult region.

Having worked for some 28 years with titanium ores, your speaker could not miss this opportunity to tell something about recent developments in that industry. Here, of course, we are encroaching on a mineral that is both an industrial mineral—since it is used to manufacture a pigment in a very large way—and also an ore of titanium metal. Fascinating as the metal side of the story is, we must keep our attention on the industrial mineral side, and certainly there is plenty of opportunity to talk at length on that subject.

The reason titanium oxide has made such an outstandingly useful white pigment may not be known to some in the audience. I will try to cover this in a few sentences. A pigment must be chemically inert, so that it will not be affected by atmospheric chemicals, as lead compounds are, but it must have a high degree of hiding power, so that a thin film of paint will hide the dingy old surface. When it is used as a filler in paper, the printing on one side of a thin sheet of paper will not interfere with the legibility of the printing on the other side. *Hiding power* is a euphemism for *index of refraction*, a property of light as it passes through a crystalline substance, about which most of you geologists have learned in your courses in optical mineralogy. A diamond is brilliant because most of the light entering it is bounced back to the observer. Quartz is dull, since most of the light entering the crystal is absorbed by what is back of it. Now if you could just paint your house with diamonds! Wait a minute —the titanium oxide compound called *rutile* has a higher index of refraction than the diamond, so when you use titanium paint, you have done a better job than if you had painted your house with diamonds!

Although titanium is the ninth most abundant element in the earth's crust—there is a small percentage in any rock, sand, or earth that could be found—the black mineral ilmenite has been the principal raw material for pigment manufacturers. Mention has been made of the black beaches of Travancore in South India, on which the sand is made up of 60 to 90 pct ilmenite. Very few places in the world have been found where a like concentration occurs, at least in commercial quantities. We had to turn to old sand bars and shore lines on which the concentration was much lower, but the tonnage available is large and the working conditions favorable.

Rock deposits of ilmenite mixed with hematite or magnetite are found in many places. Examples of the former are deposits at Allard Lake in Eastern Quebec and in Southern Norway. Titaniferous magnetites are numerous, but the only one worked in a large way is that in the Adirondack Mountains, at Tahawus, N. Y., where the National Lead Co. has been operating on a very large scale since 1942.

Since the Allard Lake ore proved difficult to separate by ore dressing methods, the operating company, Quebec Iron and Titanium Corp., has developed a metallurgical process to smelt the ore, making a usable pig iron, and a titanium-rich slag. Whereas the highest grade Florida ilmenite assays 63 pct titanium oxide, the slag assays 73 pct and has proved to be a very desirable material for pigment manufacture.

The titanium deposit at Pluma Hidalgo, in the state of Oaxaca, Mexico, is the most challenging of all. The mineralogy and geology, the problems of ore genesis, and the determination of commercial grade can fascinate the geologist, but the engineering, construction, and political problems can baffle the most experienced observer. The ore is a mixture of ilmenite and rutile in a feldspar rock. The feldspar has been identified as anorthoclase. The ore has many similarities with that at Piney River, Va., described by Clarence Ross. A number of those attending the Geological Congress in Mexico last September had the privilege of visiting the property. I believe that the owners are still not ready to decide whether they have a mine or not.

When we turn our attention to specialty industrial minerals, of smaller dollar volume, we find many materials occurring in every variety of geological deposit and presenting all sorts of problems in the fields of beneficiation, industrial application, and marketing. Many of the products are synthetics, made from other industrial minerals. To mention only a few, there are abrasive materials, mica, feldspar and nepheline, talc and pyrophyllite, diamonds and other precious stones, graphite, zircon, oxygen and other gases. There seems to be no limit to the diversity of problems presented.

Every reader was thrilled a few weeks ago by the announcement that General Electric Co. had synthesized an abrasive from boron nitride that is

harder than a diamond—most welcome news to metal finishers, since industrial diamonds have not been in excess supply and known world reserves will not meet the growing demand very long. This news follows by only a year or so the similar thrilling announcement from the same company that diamonds had been synthesized. In the last few years we have watched other important developments in synthesis—the growing of synthetic quartz crystals, the production of synthetic mica, the production of beautiful gem stones like rutile and strontium titanate, and synthetic emeralds. Numerous super-refractories and abrasives have been made. A new super-refractory hafnium carbide was announced last year and, of course, various zirconium carbides and di-borides have been made recently. These spectacular developments from our research laboratories whet our appetites for more miracles. I, for one, am waiting impatiently for three more miracles: 1) production of an inorganic fiber that can be spun and woven into a strong cloth, which will withstand temperatures up to 1500°C and can be made cheaply enough for general use in many fields of industry; 2) large-scale commercial production of HF or synthetic calcium fluoride from phosphate rock at reasonable cost—pilot plant tests have shown that the reactions are possible; and 3) production of elemental sulfur from the SO_2 in smelter gases. That the latter problem is one of major importance is illustrated by the statement that one large smelter in Canada throws out into the Canadian sky the equivalent of one million tons of sulfur per year that is not only lost, but is a detriment to the community. I have not tried to estimate the total amount of sulfur belched from the stacks of the copper smelters of the West and Southwest. This third miracle is on the road to achievement, since one of the sulfur companies is constructing a pilot plant at Sudbury, Ont., now to test a process for recovering sulfur from the smelter gases.

There is one industrial mineral in the specialty class, lithium ore, that has been much more in the news lately than seems to this observer to be justified. R. W. Hyde, writing in the *Canadian Mining Journal* for May 1956, states that six plants now have an annual capacity of 23,750,000 lb of lithium carbonate equivalent, whereas the 1956 demand was estimated at 10,680,000 lb and the 1960 demand, estimated, will be only 15,360,000 lb, or 64 pct of 1956 plant capacity. At this meeting a paper by P. E. Landolt (see April, page 460) cited larger figures for both consumption and plant capacity. The ratio of consumption to capacity between them, however, remained about 65 pct. Since 15,360,000 lb is only 7680 tons, there does not seem to be the justification for a dozen mines in Canada, the U. S., and Rhodesia rushing into production. It would seem that the glamor of the future potential of the fusion reactor in which an isotope of lithium is supposed to be needed has stimulated more optimism than the immediate situation justifies. There are industrial uses for lithium compounds in greases, ceramics and glass, aluminum welding, air conditioning, and in the alkaline storage battery. Military and atomic energy uses are expected to take only about 17 pct of the requirements both in 1956 and 1960. Mr. Landolt, at this meeting, stated that AEC and other classified uses are probably larger than the figure of 17 pct here used, following R. W. Hyde. Even so, these classified applications are not and probably will not be large enough to use all of the capacity now installed. Possibly the biggest potential for the whole industry is in new uses for lithium metal, which has the remarkable property of remaining liquid over a very wide range of temperature, from 186° to 1336°C. However, this property is also shared by the much cheaper similar metal, sodium.

As we reach the end of this review of outstanding developments and subjects of interest in the industrial mineral field, which attract the attention of a geologist, we return to the question: Is water an industrial mineral? One cannot argue against it, since water is used in the actual production of scores of industrial products as one of the component raw materials, for example, in sulfuric acid. A geologist, working for a large industrial company, may well find water problems an active part of his assignment. To solve many of these problems, frequently difficult, even obscure geological features must be studied, which are very fascinating. Looking back over 30 years of work covering most diverse assignments, I believe that one of the most satisfying jobs was in connection with the establishment in the mid-thirties of a reservoir in east central New Jersey. In that area the three neighboring plants of du Pont, Hercules Powder Co., and National Lead Co. were drawing water from the bottom member of the Cretaceous series, as was also the city of Perth Amboy, and other users. Test drilling showed that a tongue of salt water was being sucked into the aquifer, and that if this tongue were allowed to continue to grow, it would in time render the aquifer useless. A small reservoir was established on a small stream, over the Oldbridge sand, there exposed on the surface. When wells were placed around the periphery of this reservior they were continually supplied, from leakage into the ground, with partially filtered and cool water. It was an early development of natural recharge, now so widely employed in many places. The chemical plants have been greatly expanded, and their water needs have much increased, without drawing further on the deep sand. Credit for this development should go first to Henry C. Barksdale of the U. S. Geological Survey and engineers of the du Pont Co., with whom it was such a pleasure to work on so interesting a problem.

On the whole, however, although water may well be an industrial mineral, the problems of its occurrence and production are so special that one versed in and busy with other industrial minerals may well spread himself too thin if he attempts to cover that field also. In du Pont there is now a very capable group in the engineering department called the *water boys*, including a very competent geologist formerly with the U. S. Reclamation Service.

Now, in conclusion, may I emphasize that the real purpose of this analysis is to arouse in students just entering the field of economic geology an interest in the industrial mineral field, and to give them a small glimpse of the challenge that this large field offers. May I urge also that our major colleges and universities re-examine their curricula to find more room to give some of their students the wide and diverse training required for work with industrial minerals. These students may have to be relieved from the abstruse and erudite aspects of theoretical geological studies, so dear to the hearts of many of the more academic-minded of the staffs, and be given time to take courses in the mining and economic departments of the schools they are attending.

Discussion of this paper sent (2 copies) to AIME before July 31, 1957, will appear in MINING ENGINEERING.

Isotopic Constitutions And Origins of Lead Ores

by R. D. Russell and R. M. Farquhar

ISOTOPIC tracers have become an important aid in following the progress of chemical processes in the laboratory. It has recently been found possible to utilize a system of naturally existing isotopic tracers to obtain information about the geological history of lead ores. Common lead, such as is found in lead deposits, is a mixture of four stable isotopes having atomic weights 204, 206, 207, and 208.

Of these, the last three are identical with the lead isotopes produced as stable end products of the radioactive decays of uranium and thorium: the first, lead-204, is not known to be produced on the surface of the earth by any process. Since uranium and thorium occur in the surface regions of the earth in amounts comparable with lead, and since the half-lives of uranium and thorium isotopes are of the same order as the age of the earth, they produce the radiogenic lead isotopes in amounts comparable to the amount of nonradiogenic lead present. Every significant exposure of a sample of lead to uranium and thorium will therefore lead to the *permanent* alteration of the lead isotope ratios in that sample.

It is this unique property of lead that serves as a means of tracing the history of a lead sample in terms of its contacts with the radioactive elements.

If lead from a lead mineral has been analyzed with a mass spectrometer, the measured isotope ratios are determined entirely by the isotope ratios of primeval lead, which are identical for all minerals, and by the particular history of the sample. It follows that for samples from any particular geological area, observed differences in the isotopic composition are enough to distinguish different geological histories. An illustration of the qualitative application of this statement is given in Table I by analyses of some galenas from the western Cordillera. Samples from deposits in Pre-Cambrian sediments have very different lead isotope ratios from those of the ores in the Paleozoic sediments. Although the two types are associated closely geographically, it is apparent that they have had quite different histories and have probably been emplaced at quite different times, as the ideas outlined in the following section suggest. Even when applied quantitatively, a lead isotope analysis can never indicate a unique history of any lead sample. However, it greatly restricts the choices available and combined with other geological and geochemical data can lead to a much better understanding of the genesis of lead ores.

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General Character of Lead Isotope Variations: Early isotopic analyses of common leads by Nier[1] showed that geologically younger leads were generally richer in isotopes of masses 206, 207, and 208, with respect to that of mass 204. This regularity of measured lead isotope ratios can be easily observed by plotting each of the ratios Pb^{207}/Pb^{204} and Pb^{208}/Pb^{204} against the ratio Pb^{206}/Pb^{204}.

Table I. Lead Isotope Ratios for Galenas from the Cordilleran Region of Western Canada

Sample Number	Location	Pb^{206}/Pb^{204}	Pb^{207}/Pb^{204}	Pb^{208}/Pb^{204}	Age, Millions of Years
200	Sullivan mine, Kimberley, B. C.	16.77	15.77	36.81	940±300
514	North Star mine	16.77	15.82	37.17	910±300
512	Sullivan mine, Kimberley, B. C.	16.82	15.80	37.15	900±300
208	North Star mine, Cranbrook, B. C. (Cerussite)	16.93	15.96	37.18	885±310
513	Blue Bell mine, B. C.	17.86	15.89	38.88	
212	Monarch mine, B. C.	19.37	16.28	40.30	
210	West Kootenay, B. C.	19.49	16.13	40.04	
215	Keno Hill, Mayo, Yukon	19.58	16.05	40.15	
209	Torbritt, B. C.	19.70	16.24	39.92	

In both graphs the points lie scattered closely about a well defined mean curve. It was immediately supposed that this regularity resulted from the growth of all leads from a common primeval lead present at some time, T_0, early in the earth's history. Lead in the outer part of the earth would become continually enriched in the radiogenic isotopes as a result of the uranium and thorium intimately associated with it. The subsequent extraction of some of this lead and formation of a lead mineral free of the radioactive parents provide samples of lead existing in the earth at the time of mineralization, T. Younger leads in general will be richer in the radiogenic isotopes because they have been associated with uranium and thorium for a longer time. Then lead ratios would be given by the formulae:

$$(Pb^{206}/Pb^{204})_T = (Pb^{206}/Pb^{204}{}_{T_0}) + \int_T^{T_0} (U^{238}/Pb^{204})\, \lambda \, dt$$

$$(Pb^{207}/Pb^{204})_T = (Pb^{207}/Pb^{204})_{T_0} + \int_T^{T_0} (U^{235}/Pb^{204})\, \lambda' \, dt$$

$$(Pb^{208}/Pb^{204})_T = (Pb^{208}/Pb^{204})_{T_0} + \int_T^{T_0} (Th^{232}/Pb^{204})\, \lambda'' \, dt \quad [1]$$

where λ, λ', and λ'' are the decay constants of U^{238}, U^{235} and Th^{232}.

Summaries of measurements of radioactivity of surface rocks, such as given by Faul,[2] are of limited

help in estimating ratios of uranium and thorium to lead in different parts of the earth and at different times in its history. Consequently the ratios are usually taken as a constant multiplied by an exponential factor representing the effect of radioactive decay. On this assumption, which effectively ignores the possibility of any process other than radioactivity changing the distribution of lead, uranium and thorium in the earth, it is possible to perform the integrations in Eq. 1 to give:

$$(Pb^{206}/Pb^{204})_T = (Pb^{206}/Pb^{204})_{T_0} + (U^{238}/Pb^{204})_{T_0}\,(1 - e^{-\lambda(T_0-T)})$$

$$(Pb^{207}/Pb^{204})_T = (Pb^{207}/Pb^{204})_{T_0} + (U^{235}/Pb^{204})_{T_0}\,(1 - e^{-\lambda'(T_0-T)})$$

$$(Pb^{208}/Pb^{204})_T = (Pb^{208}/Pb^{204})_{T_0} + (Th^{232}/Pb^{204})_{T_0}\,(1 - e^{-\lambda''(T_0-T)}). \quad [2]$$

The first two of these equations can be combined to give:

$$\frac{(Pb^{207}/Pb^{204})_T - (Pb^{207}/Pb^{204})_{T_0}}{(Pb^{206}/Pb^{204})_T - (Pb^{206}/Pb^{204})_{T_0}} = \left(\frac{U^{235}}{U^{238}}\right)_{T_0} \left\{\frac{1 - e^{\lambda'(T_0-T)}}{1 - e^{\lambda(T_0-T)}}\right\}$$

$$= \left(\frac{U^{235}}{U^{238}}\right)_{\text{present}} \left\{\frac{e^{\lambda' T_0} - e^{\lambda' T}}{e^{\lambda T_0} - e^{\lambda T}}\right\}. \quad [3]$$

Eqs. 2 and 3 are the equations committed to memory by everyone concerned with lead isotopes.

These assumptions may seem surprising in view of the belief held by some that the rocks forming the crust of the earth have not been present as such since the solidification of a molten earth, but that the continents have been slowly evolving by the addition of new material from the upper part of the earth's mantle. The idea of a gradual evolution of the earth's surface features does not at first seem compatible with the supposition of a permanent, unchanging source for lead ores. Nor does the assumption of a homogeneous source seem compatible with the wide difference in the radioactivity of surface rocks. However, if the theory of continental growth from material derived from the mantle is correct, then lead, as well as the other elements in the crust, must be derived from the mantle. The major contributions of radiogenic isotopes to lead would not occur in the crustal rocks, but in the mantle. The observed regularity of lead isotope abundances is easily explained if the mantle is moderately uniform on a broad scale. Thus the abundances are apparently consistent both with the theory of continental growth and with the observations that many Canadian ore deposits in the Pre-Cambrian seem closely associated with deep faults and only less directly with major igneous intrusives.[8]

In line with these assumptions, the following sequence of events can be visualized as the history of lead ores:

1) At the time of its formation, the earth contained in its mantle primeval lead disseminated with the uranium and thorium present.

2) Lead in any part of the mantle was altered by the addition of radiogenic isotopes until the time of local orogeny.

3) At the time of local orogeny, lead was brought to the surface and was incorporated into crustal rocks.

Then follow five alternatives:

4a) The lead remains forever disseminated in the rocks, in which case it is not of concern in the study of macroscopic lead minerals.

4b) Lead is incorporated directly into minerals, in which case it has had a simple history and is known as an *ordinary* lead.

4c) It is incorporated in rocks having uranium/lead and thorium/lead ratios similar to the mantle and subsequently forms a lead mineral. Isotopically, this lead is indistinguishable from lead arriving directly from the mantle at the time of mineralization.

4d) It is incorporated in rocks having uranium/lead and thorium/lead ratios much lower than the mantle and subsequently forms a lead mineral. Isotopically this lead is not very different from that in case 4b.

4e) It is incorporated into rocks having uranium/lead and thorium/lead ratios much larger than the mantle and then forms a lead mineral. This forms an *anomalous* lead that requires a more complex mathematical representation than do any of the others. The distinction between cases 4c, 4d, and 4e is to some extent arbitrary, but it greatly simplifies discussion of lead isotope abundances.

Estimating the Ages of *Ordinary* Leads: In view of the fact that *ordinary* leads, in the sense used above, closely follow an abundance-age relationship, it is a natural step to try to use such relationships to date *ordinary* galenas. To do this, it is more convenient to rewrite Eq. 2 in the form:

$$\begin{aligned}(Pb^{206}/Pb^{204})_T &= a - \alpha V\ (e^{\lambda T} - 1),\\ (Pb^{207}/Pb^{204})_T &= b - V\ (e^{\lambda' T} - 1),\\ (Pb^{208}/Pb^{204})_T &= c - W\ (e^{\lambda'' T} - 1). \quad [4]\end{aligned}$$

Here a, b, and c are the Pb^{206}/Pb^{204}, Pb^{207}/Pb^{204}, and Pb^{208}/Pb^{204} ratios for very young lead samples, W is the present average value of the ratio Th^{232}/Pb^{204}, V is the present average value of the ratio U^{235}/Pb^{204}, α is the present ratio of U^{238} to U^{235}, and all other symbols are the same as those previously defined.

The first and third of these equations are the ones that have been used by the workers at the University of Toronto to date many lead ores. They may be applied only to *ordinary* leads and only if the supposition of the derivation of the leads from a rather homogeneous mantle is valid. The equations have been combined in a different form by F. G. Houtermans[4] for age determinations, but the results obtained by the two methods are very much the same.

Table II. Some Examples of Common Lead Ages

Location	Pb^{206}/Pb^{204}	Pb^{207}/Pb^{204}	Pb^{208}/Pb^{204}	Age, Millions of Years
Con mine 1250′ level, Yellowknife Northwest Territories (T-446)	14.25	15.26	34.42	2300±150
Steeprock Lake, Ont. (T-404)	13.94	14.83	33.75	2410±130
Kokosho quarry, near Kulu Matundu, Uele, N. Congo (T-616)	12.81	14.39	32.84	2540±110
Kalgoorlie, Western Australia (T-503)	13.89	15.08	33.88	2400±130
Anacon mine, Quebec (T-560)	16.53	15.63	36.42	1240±100
Ciglen Claims, Lake Baskatong, Quebec (T-520)	16.80	15.64	36.71	1160±100

Table II lists some calculated ages of some typical *ordinary* galenas. Present indications are that these ages are not in conflict with those obtained for the same regions by other methods.

Anomalous Leads: Early in the study of common lead isotope abundance variations, it became apparent that certain leads could not be fitted to any of the above simple theories. The Joplin ores, which are of this type, were finally rejected by Holmes[5] for his determination of the earth's age. They had to be rejected by Bullard and Stanley[6] before their age of the earth calculations would yield any sensible result, and they could not be used by Alpher and Herman[7] in the development of their common lead abundance-time curves.

Table III. Lead Isotopic Abundances of Sudbury Galenas

Number	Location	Pb^{206}/Pb^{204}	Pb^{207}/Pb^{204}	Pb^{208}/Pb^{204}
1	McKim mine (1000 ft)	22.89	16.72	44.92
2	McKim mine (960 ft)	23.03	16.69	45.19
3	McKim mine (800 ft)	16.30	15.85	36.97
4	McKim mine (600 ft)	16.43	15.96	36.93
5	Falconbridge mine (3300 ft)	24.29	17.04	45.70
6	Falconbridge mine (2400 ft)	23.70	16.92	45.35
7	Falconbridge mine (1700 ft)	24.20	16.95	45.58
8	Frood mine (disseminated in wall)	15.99	15.84	36.56
9	Frood mine (post ore slip)	23.10	16.90	45.04
10	Garson mine	22.95	16.69	44.79
11	Garson mine (post ore slip)	23.00	16.61	44.78
12	Worthington mine	26.00	16.94	52.21
13	Hardy mine (750 ft)	23.23	16.77	52.64
14	Fairbank township (deformed micropegmatite)	16.20	15.76	36.90
15	Treadwell Yukon (center of basin)	16.15	15.60	35.94

A second suite of anomalous leads was discovered in the region of Sudbury, Ont. The Sudbury leads have Pb^{206}/Pb^{204} and Pb^{208}/Pb^{204} ratios that appear even more anomalous than those for Joplin leads. The fact that the Pb^{207}/Pb^{204} ratios are not so anomalously large indicates that the excess radiogenic lead must have been generated in a relatively late stage of the earth's history when uranium-235 was relatively rare. Suites of samples from the Sudbury area and the Joplin-Tri-State area have been analyzed at Toronto with the results shown in Tables III and IV.

Table IV. Lead Isotope Abundances of Tri-State Mine Galenas

Number	Mine	Bed	Pb^{206}/Pb^{204}	Pb^{207}/Pb^{204}	Pb^{208}/Pb^{204}
316	Diamond Joe	Chester limestone	21.38	16.16	41.03
318	Weber-Westside	D-E	22.15	16.21	41.63
320	Howe (average of two analyses)	E	22.20	16.27	41.88
315	Federal-Jarrett	G-H	22.70	16.25	42.16
319	Kitty	G-H	22.73	16.31	42.07
314	Weber-Westside	G-H	22.12	16.22	41.63
317	Grace B	J	22.77	16.29	42.25
321	Otis White	K	22.77	16.28	42.13
323	Blue Goose No. 1	M	22.07	16.24	41.87
231	Westside	M	22.16	16.31	41.98
322	Blue Goose No. 2 (average of two analyses)	O	21.83	16.14	41.35

The Sudbury ores show a remarkable variation of isotopic constitution for samples even from the same mine. Such a variation is not found in the case of deposits that do not contain anomalous leads. This is borne out by the analyses of leads from other mines—which are apparently not anomalous—which come from a greater range of depths than the Sudbury leads and which show no variations in isotopic constitution. (See Table V.)

To obtain information about the age of the Sudbury galenas it has been postulated that these leads were mixtures in varying proportions of a single radiogenic lead and a single common lead of the nonanomalous type. By means of a simple least squares calculation[8] the ratio Pb^{207}/Pb^{206} in the radiogenic lead was determined to be 0.134 ± 0.007. It can be calculated that uranium was generating lead isotopes in these proportions 1300 million years ago.

Table V. Lead Isotope Ratios for Samples from Bunker Hill and Sullivan Mines, Idaho

Number	Depth with Respect to Sea Level, Ft	Pb^{206}/Pb^{204}	Pb^{207}/Pb^{204}	Pb^{208}/Pb^{204}
577	3150	16.69	15.82	36.79
578	1200	16.55	15.72	36.60
579	850	16.56	15.73	36.68
580	−150	16.58	15.75	36.75
581	−350	16.54	15.72	36.62

It follows that the lead must have been in contact with uranium at least as recently as 1300 million years ago. This age is then an upper limit to the age of these minerals.

Five of the samples analyzed do not appear to be anomalous and can be dated by the methods described previously. The ages obtained are in excellent agreement, and the mean age of 1250 million years agrees within the limits of error with the time of beginning of the Grenville orogeny about 1100 million years ago. The Sudbury ores appear to be associated with a series of faults that start at the northern border of the Grenville geological province and extend into the older Keewatin province to the north.

The variation of the Tri-State abundances is not sufficient to apply successfully least squares calculations of the above type. However, variations do exist and do seem to be related to the position of the ore in the stratigraphic column. No theory has yet been put forward to explain the variation of the Tri-State lead isotope abundances.

The most important point to be made is that the deposition of these ores must have involved additions of considerable quantities of radiogenic lead, possibly leached from older rock formations that were relatively rich in uranium and thorium. Many more samples from this region must be analyzed if further progress on this problem is to be made.

In the course of analyses of various other suites of lead minerals it was found that some samples from the Broken Hill area, N.S.W., Australia, exhibited the properties indicative of *anomalous* leads.

Table VI. Isotopic Analyses of Leads from Broken Hill, N. S. W.

Number	Sample		Pb^{206}/Pb^{204}	Pb^{207}/Fb^{204}	Pb^{208}/Pb^{204}
667	No. 3 Lens	Main Ore bodies	16.23	15.69	36.17
668	Bewteen No. 2 and No. 3 Lens	Main Ore bodies	16.24	15.69	36.14
669	No. 2 Lens	Main Ore bodies	16.12	15.57	35.85
670	Rhodonitic zinc lode	Main Ore bodies	16.14	15.57	35.83
671	No. 1 Lens	Main Ore bodies	16.18	15.64	36.05
672	Siliceous zinc lode	Main Ore bodies	16.22	15.67	36.15
721	Mayflower	Satellite Ore bodies	18.15	15.96	39.01
723	Terrible Dick	Satellite Ore bodies	18.17	15.94	39.17
724	3000 ft south of Apollyon Mine	Satellite Ore bodies	18.17	15.91	39.13
725	Daydream	Satellite Ore bodies	18.03	15.90	39.08
726	Victoria extended	Satellite Ore bodies	18.16	15.96	39.17
727	Pioneer (Thackaringa)	Satellite Ore bodies	17.66	15.88	38.71

Results included in Table VI show that the main Broken Hill orebodies apparently consist of ordinary lead uncontaminated by the radiogenic additions evident in the leads from the surrounding satellite

deposits. A mathematical analysis similar to that performed on the Sudbury leads gives an *ordinary* lead age of 1430 m.y. using the samples from the main orebodies and an upper limit to the time of radiogenic additions of 1490 m.y. using all the analyses.

As a further check on the hypothesis that the *anomalous* leads have had histories considerably different from the ordinary leads, a series of spectroscopic analyses was made by J. E. Hawley, Queen's University, Kingston. The elements bismuth and tin present in the galena samples from the main orebodies were found to be absent or in much lower concentrations in the samples from the satellite deposits. This gives further support to the writers' ideas regarding the fundamental differences between anomalous and ordinary leads.

Conclusion

This article has pointed out four fundamental ways in which a knowledge of isotope ratios of common leads may be of assistance in understanding the genesis of ore deposits. The first is their use to distinguish leads arising from separate mineralizations, as was described for the western Cordillera leads. The second is their use in estimating the age of deposition of *ordinary* leads. This is the only method yet devised for directly dating most ore-bearing veins. The third is their use in determining the genetic relationships among *anomalous* leads. The fourth is the general observation that to date the regularity in the abundance ratios found in lead ores has been explained only by assuming that *ordinary* lead ores have come unchanged from a uniform source containing uranium thorium and lead. The most likely uniform source seems to be the mantle. If this explanation is true the great majority of lead ores have risen directly from the mantle, during periods of orogeny.

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Discussion of this paper sent (2 copies) to AIME before June 30, 1957, will be published in MINING ENGINEERING.

Differentiation of Igneous Rocks and Ore Deposition in Peru

by W. C. Lacy

Fig. 1—Peru, showing location of areas in which relations igneous rocks and mineral deposits were studied. Localities represented in study of igneous rocks are starred.

A WIDE variety of metalliferous deposits in Peru shows a close and consistent relationship to intrusive and extrusive igneous rocks. This relationship furnishes a clue to the composition of ore-bearing fluids and to the timing in separation of these fluids from differentiation magma.

Conclusions presented here are based on ten years' study of a large number of metalliferous deposits in Peru. The most important of these areas are shown in Fig. 1.

The structural relationship of metal mineralization to the intrusive series and of the members of the series to each other can be illustrated by three examples:

The well described Cerro de Pasco (Ref. 1, p. 160) sulfide mass shown in Fig. 2 is localized along the eastern contact of an agglomerate-filled crater. Quartz-monzonite porphyry and related intrusive breccias, which in places border the pyrite mass on west, are replaced by the pyrite and cut by later transverse vein structures. Late unmineralized but

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Fig. 2—Generalized map of surface (inset) and 600 level at Cerro de Pasco.

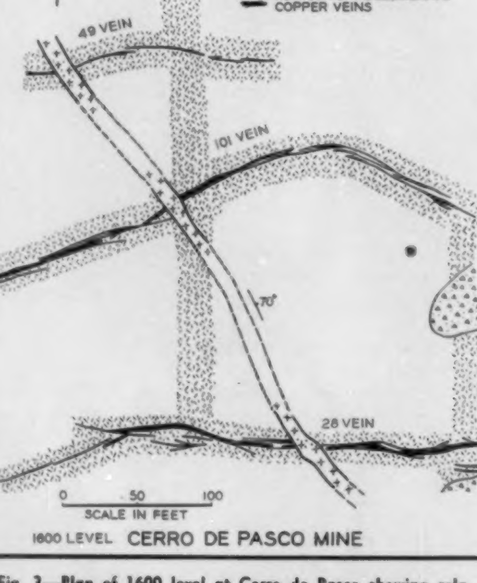

Fig. 3—Plan of 1600 level at Cerro de Pasco showing relation of post-ore dikes to vein structures.

strongly altered albitized quartz-latite to latite porphyry dikes cut the transverse veins and the northern portion of the pyrite mass, Fig. 3.

A folded and faulted sedimentary and volcanic sequence of rocks at Morococha (Ref. 1, p. 170) is cut by quartz-diorite, granodiorite, quartz-monzonite, and quartz-monzonite porphyry intrusives, shown in Fig. 5. Barren pyrite masses are found tangential to the granodiorite and quartz-monzonite intrusive bodies of the San Francisco and Potosi stocks. Pyrite masses containing ore minerals occur next to quartz-monzonite porphyry intrusives, such as the Gertrudis and San Nicolas stocks. Ore minerals were introduced after at least partial solidification of the intrusives, as indicated by mineralized fractures, which die out as traced from the contacts into the stocks. No post-ore intrusives have been identified.

At the newly developed Cuajone porphyry copper deposit in southern Peru, quartz-diorite, quartz-monzonite porphyry, latite porphyry, and related intrusive breccias have intruded a warped series, Fig. 4 of Cretaceous (?) volcanics. Most sulfide mineralization was introduced prior to intrusion of latite porphyry and breccia dikes and after solidification and shattering of the quartz-monzonite porphyry.

Intrusive rocks in all districts examined have similar mineralogical and textural characteristics as well as consistent age relationships. Except for very late basaltic dikes, which are seemingly unrelated to mineralized areas, the more calcic intrusives are always older.

Pre-Sulfide Intrusives: Quartz-diorite,* which occurs in large stocks or batholiths, is xenomorphic granular in texture, containing unaltered hornblende, augite, and andesine subhedrons, with a small quantity of intergranular fine-grained quartz and orthoclase.

Granodiorite intrusives occur as large stocks or batholiths. These have a hypautomorphic granular texture in which most of the andesine-oligoclase is euhedral to subhedral, with interstices filled with *aplitic* quartz and orthoclase. The ferromagnesian mineral is essentially hornblende. Normally all minerals are unaltered except adjacent to sulfide mineralization.

Quartz-monzonite occurs in stocks with a texture similar to the granodiorite. It contains a somewhat larger percentage of the *aplitic* quartz and orthoclase interstitial to oligoclase, biotite, and hornblende euhedrons and subhedrons. The minerals are generally unaltered except where adjacent to sulfide mineralization.

Quartz-monzonite is found as small stocks or dikes containing phenocrysts of quartz, oligoclase, and biotite in a fine *aplitic* groundmass composed essentially of quartz and orthoclase with small quantities of oligoclase. A porphyritic texture is developed. Widespread alteration of these intrusives is characteristic, extending considerable distances from any known sulfide mineralization.

Post-Sulfide Intrusives: Post-sulfide intrusives occur as small dikes ranging in composition from quartz-latite to latite. They are generally porphyritic but may develop an implication texture or a plume-like intergrowth of quartz, orthoclase, and

* Lindgren (Ref. 2, p. 277) defined a quartz-monzonite as having 20 to 40 pct alkali feldspar, assuming 60 pct total feldspar content, the soda-lime feldspar being a calcic oligoclase or andesine. With 8 to 20 pct alkali feldspar the rock becomes a granodiorite, and below 8 pct a quartz-diorite.

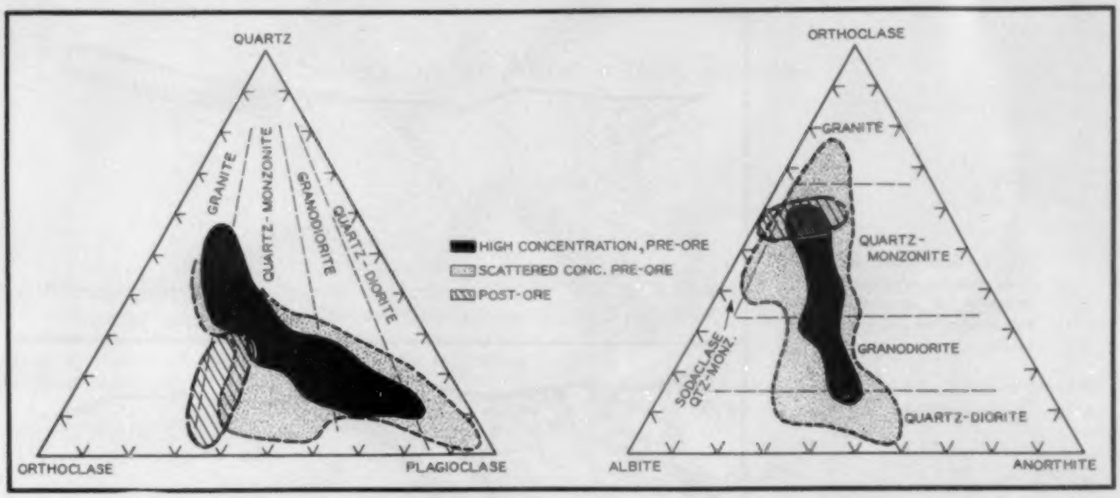

Fig. 4—Ternary diagrams showing compositional variations of igneous rocks of Peru.

sodic plagioclase. Biotite is less abundant than in the quartz-monzonite porphyry and is supplanted in part by muscovite. The dikes are generally altered, with alteration unrelated to mineralization. They commonly are rich in manganese and weather black in outcroppings.

Mineral Variations: Mineral compositions of some 200 specimens of igneous rock from localities shown in Fig. 1 were determined microscopically in thin section and are plotted in Fig. 4. (Late post-mineralization basaltic dikes geographically unrelated to mineralized districts were not included.) Compositions of the quartz-diorite, granodiorite, and quartz-monzonite intrusives were accurately determined, but mineralogical determinations in quartz-monzonite porphyry and some of the post-sulfide intrusives were hindered by extensive alteration, and considerable extrapolation was required. However, there appears little doubt that the rock types all fall within the same or similar magma series, and that these intrusives exposed at the surface are the upward manifestation of a differentiating magma in depth.

Compositional variations of the pre-sulfide intrusives range from quartz-diorite to alaskite, with a concentration of quartz and orthoclase in the later fractions. There occurs a sharp break in the trend corresponding to the period of ore mineralization, with a sharp decline in the quantity of free quartz in the post-sulfide intrusives, and an increase in sodium relative to calcium.

Correlation of Intrusive and Extrusive Activity: Volcanic activity in Peru began in late Cretaceous time and feebly continues today; however, the most intense activity preceded metalization occurring in Early Tertiary time. These eruptives contain a preponderance of thick andesite to trachyte flows and pyroclastics and are thickest in a belt lying west of the continental divide and west of the centers of mineralization. Only locally are dacite or rhyolites important. This great thickness of volcanic rocks is poorly dated, but all available data indicate that they were erupted either prior to or simultaneously with the quartz-diorite member of the intrusive sequence represented in the mineralized districts. Later local explosive phases are closely associated with, but preceded, quartz-monzonite porphyry intrusives. In these extrusives dacite tuffs predominate.

Metalliferous Deposits: Contact zones of quartz-diorite and granodiorite intrusives commonly contain small, irregular magnetite bodies with minor

Table I. Summary of Relations of Igneous Rocks to Ore Deposits in Peru

Pre-Ore Intrusives	Type of Pluton	Texture	Plagioclase	Femags	Volcanic Activity	Mineral Deposits
Quartz-diorite:	Large stocks	Xenomorphic granular	Andesine (usually fresh)	Augite, hornblende	Widespread andesite to trachite flows pyroclastics (earlier or contemporaneous)	Magnetite
Granodiorite, quartz-monzonite:	Large stocks to batholiths	Hypautomorphic granular	Andesine-oligoclase (usually fresh)	Hornblende, augite	Limited	Barren pyrite
Quartz-monzonite porphyry:	Small stocks, dikes and sills	Porphyritic (quartz and plagioclase phenocrysts)	Oligoclase-andesine (usually altered)	Biotite (hornblende)	Local explosive dacite agglomerates, and tuffs, breccia pipes	Pyrite with Cu, Zn, Pb, Au, Ag
Post-ore Intrusives	Small dikes	Porphyritic (quartz, plagioclase and orthoclase phenocrysts)	Oligoclase-albite	(Biotite)	Breccia pipes and pebble dikes	Post-ore (Ag ?)

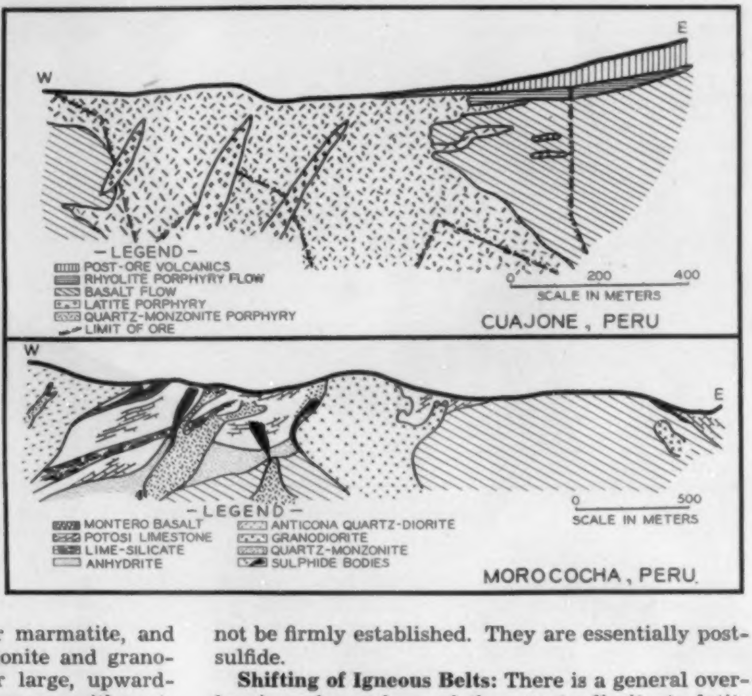

Fig. 5—Generalized sections showing relations of intrusives to mineralization at Cuajone and Morococha.

chalcopyrite, ferroan sphalerite or marmatite, and pyrite. Peripheral to quartz-monzonite and granodiorite intrusives commonly occur large, upward-flaring, barren pyrite replacement masses with roots ending in depths tangential to the intrusive contact. These are well illustrated at Morococha. Similar pyrite replacement bodies carrying ore minerals as pipes within the pyrite peripheral to the pyrite mass—or as veins cutting pyrite and intrusives—are found immediately adjacent to quartz-monzonite porphyry intrusives. Mineralization appears to have followed intrusion of the stocks closely. Occasionally sharp-walled veins cut the outer shell of an intrusive and die out toward the interior, possibly indicating incomplete consolidation at the time of fracturing and mineralization.

There is some doubt as to the nature of metalization related to latite and quartz-latite porphyry dikes. Some silver and manganese mineral deposition appears to have been introduced about the same time as these dikes, but a genetic relationship cannot be firmly established. They are essentially post-sulfide.

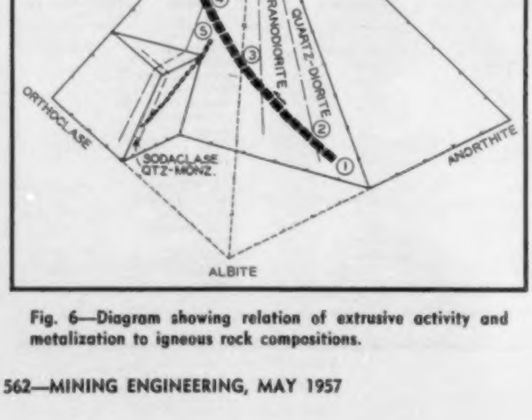

Fig. 6—Diagram showing relation of extrusive activity and metalization to igneous rock compositions.

Shifting of Igneous Belts: There is a general overlapping of members of the quartz-diorite to latite porphyry magma series, but there exists an indistinct but definite trend toward an eastward shifting of the later intrusives. In central Peru quartz-diorite is generally west of or close to the continental divide; granodiorite is found astride or close to the divide; and quartz-monzonite, quartz-monzonite porphyry, and latite porphyry intrusives are more common east of the divide. A similar trend is observed in southern Peru, where accompanying the shift of igneous rock types is a change from the porphyry-copper type of mineralization, to lead-zinc deposits, to manganese-silver deposits.

Observed relationships are summarized in Table I and illustrated in Fig. 6.

It appears from the study of relations of intrusive rocks and ore deposits in Peru that separation of ore solutions occurred late in the history of the differentiating magma and that this separation resulted in, or was accompanied by, a sharp decline in silica and lime content of the magma. By inference it is concluded that the fluids removing metals from the differentiating magma also carried away the silica and lime.

The mechanism of separation of the ore fluids is not clear, but evidence indicates that it occurred while the intrusive mass was still in a partially mobile state. Metallic components were released from the differentiating magma at various stages and not simultaneously.

Many more observations are required, particularly of intrusives that were injected during the period of metalization. A correlation should be made of the paragenesis of ore minerals with these intrusives.

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Discussion of this paper sent (2 copies) to AIME before June 30, 1957, will be published in MINING ENGINEERING.

Selection of Mine Hoist Ropes

by Lawrence Adler

MINE hoist ropes have hitherto been selected by successive approximation, a process both tedious and inexact. The proposed expression is a readily solved synthesis of existing data and the following standard equation:[1]

$$\left[W + W_r + (W + W_r)\frac{a}{g} + (W + W_r) f + B \right] n = T \qquad [1]$$

For convenience, a glossary of all terms appears on page 564.

Since rope weight (W_r) and bending load (B) are functions of unit rope weight (W_v), which in turn is a function of rope strength (T), W_r and B can be expressed in terms of T.

W_r as a Function of T: A study of the curve in Fig. 1, unit rope weight vs strength, yields Eq. 2:

$$W_v = \frac{T}{K} \qquad [2]$$

Therefore

$$W_r = W_v L = \frac{L}{K} T. \qquad [3]$$

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TN 372A. Manuscript, March 1, 1956.

B as a Function of T: From Fig. 2, unit rope weight vs diameter, Eq. 4 is obtained:

$$W_v = 1.6 d^2 \qquad [4]$$

B is related[2] to d and D, and d has been expressed in terms of W_v by Eq. 4, so the curve B vs W_v (Fig. 3) gives Eq. 5:

$$B = \frac{177{,}000}{N} W_v = \frac{177{,}000}{KN} T \qquad [5]$$

This may readily be checked from the expression[3] for a 6x19 rope, i.e.,

$$B = 288{,}000 \frac{d^3}{D}.$$

Since $d^2 = 0.625\, W_v$ and $N = \dfrac{D}{d}$, substituting into the above expression gives Eq. 6:

$$B = \frac{180{,}000}{N} W_v = \frac{180{,}000}{KN} T, \text{ which will be used.} \qquad [6]$$

Into Eq. 1 substitute Eq. 3 and Eq. 6, noting that $f = 0.02$:

$$\left[\left(W + \frac{L}{K} T \right) \left(1.02 + \frac{a}{32.2} \right) + \frac{180{,}000}{KN} T \right] n = T. \qquad [7]$$

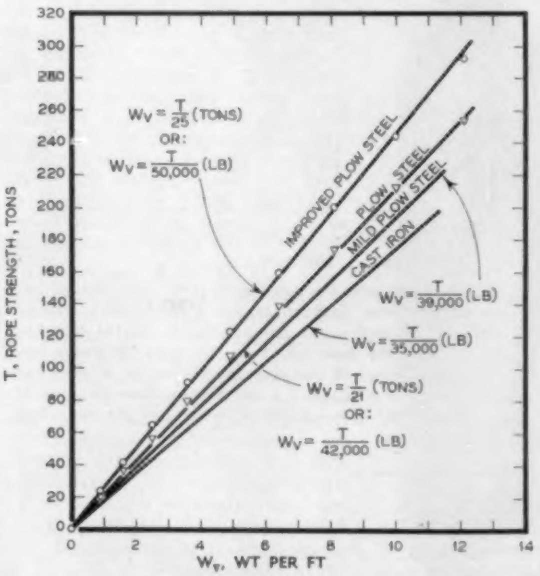

Fig. 1—Rope strength vs weight (6x19 rope).

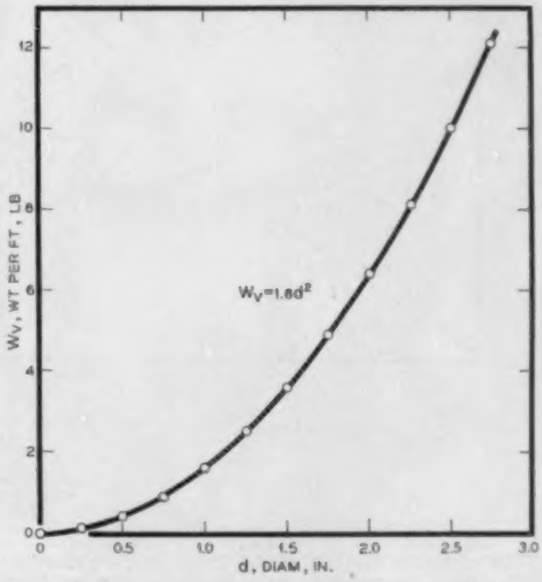

Fig. 2—Rope weight vs diameter (6x19 rope).

Solving for T in tons:

$$T = \frac{2{,}000\, KW}{\left(\frac{32.8 + a}{32.2}\right)\left(\frac{K}{n} - \frac{180{,}000}{N}\right) - L}. \quad [8]$$

Values of K are given in Table I or can be calculated easily. For example, Roebling's 1105.6×19 rope (or American Cable VHS) at $W_v = 11.00$ and

$T = 302$. Therefore $K = \frac{2000 \times 302}{11.00} = 55{,}000$.

Table I. Values of *K*

Material	K
Improved plow steel	50,000
Plow steel	42,000
Mild plow steel	39,000
Cast iron	35,000

A nomogram[4] has been prepared for repeated solutions using improved plow steel. For other materials Fig. 5 gives an approximate, minimum value.

In Eq. 7 a high value of L can make T negative, which is not possible. But for a maximum rope strength of 300 tons, a maximum acceleration of 10 ft per sec,[2] an N of 100, curves of maximum L vs W for a given n can be plotted (Fig. 4) which limit their usage.

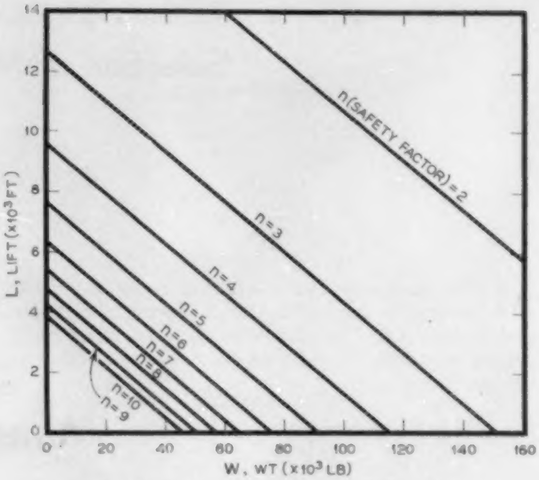

Fig. 3—Bending load vs weight (6x19 rope).

Glossary of Terms

a = acceleration, ft per sec²
B = bending load, lb
d = rope diameter, in.
D = sheave diameter, in.
f = friction coefficient (0.02)
g = gravity (32.2 ft per sec²)
K = slope of curve, unit weight vs strength
L = suspended rope length, ft
N = ratio sheave to rope diameter (D/d)
n = safety factor
T = breaking strength of rope, tons
W = suspended dead load, excluding rope, lb
W_r = suspended rope weight, lb (W_vL)
W_v = unit rope weight, lb per ft

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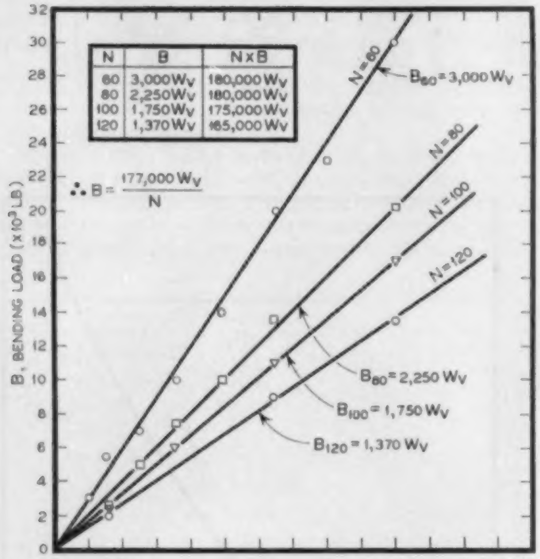

Fig. 4—Lift vs weight (6x19 rope). a = 10 ft per sec² and N = 100.

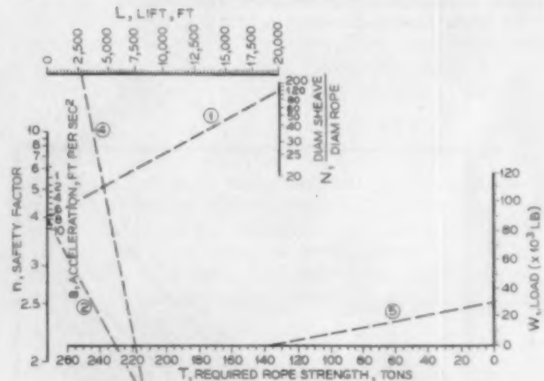

Fig. 5—Nomogram for selecting a 6x19 hoist rope of improved plow steel. Instructions: Join n and N with a straight line (*1*). Through a and perpendicular to line (*1*) draw line (*2*) down to the pivot line. From this point (*3*) draw a line (*4*) to L. Through W and perpendicular to line (*4*) draw line (*5*). Where it intersects T is the solution. Example: n = 4; L = 3000 ft; W = 30,000 lb; a = 8 ft per sec². Find T = 136 tons.

Correction

The staff wish to emphasize that Massachusetts Institute of Technology has not discovered a new element "Cn" although the title of the Transactions paper by A. M. Gaudin, D. W. Fuerstenau, and M. M. Turkanis (page 65, Mining Engineering, January 1957) contains the phrase "and Cn Ions." Free from typographical error the phrase would read "and CN Ions," which makes much better sense.

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News of . . . Society Institute Profession

Society of Mining Engineers Holds First Annual Meeting at Tampa

Plans Nearing Completion for Southeastern States Mining Conference

H. E. UHLAND

The Hillsboro Hotel in Tampa, Fla., will be the scene of the Southeastern States Mining Conference, Oct. 15 to 18, 1957. Under the direction of chairman H. E. Uhland, 11 technical sessions have been scheduled at which time 40 to 50 papers will be presented. The conference is co-sponsored by the Florida Section and the Society of Mining Engineers of AIME, the latter having chosen this conclave as its first annual meeting.

Field Trips

Two full days will be devoted to field trips. Members will have the opportunity to visit Noralyn, the largest phosphate mine and mill; the electric furnaces of The American Agricultural Chemical Co.; and the triple superphosphate plant of Davison Chemical Co. Scheduled for Thursday, October 17, this tour will include luncheon in a pastoral setting, a park on a lovely lake. On Friday, there will be a choice of a field trip to Starke, or Bunnell, to the cement plant of Lehigh which uses coquina rock as a raw material in place of limestone.

Conference Highlights

In addition to a welcoming luncheon and a banquet with special entertainment, the program committee has arranged for a *deep sea mining trip*, which should delight all fishing devotees, especially since the tackle will be provided free, and the fish guaranteed. This trip will take place on Saturday.

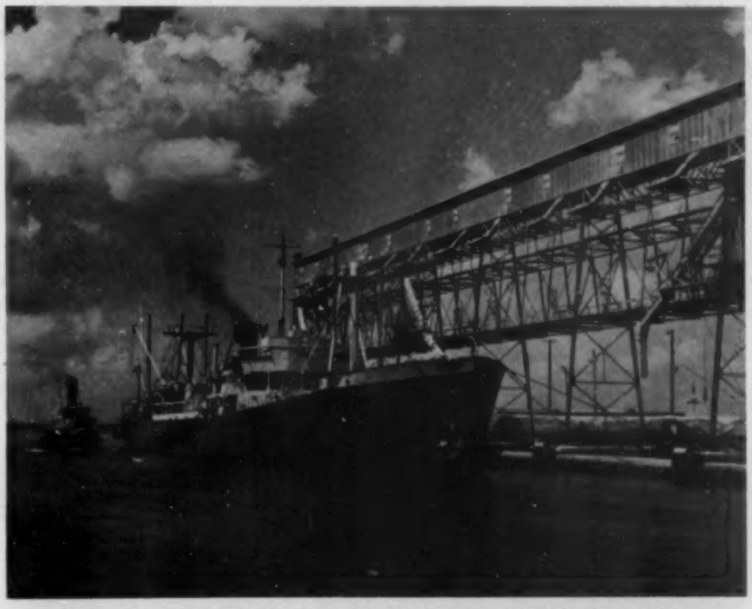
Feminine Frolics

A very full program has been arranged for the ladies too. They will take an excursion to one of Florida's most scenic spots, Cypress Gardens. A fashion show in an unusual locale, on the beach, is also featured on the gals' agenda.

Prizes for Early Birds

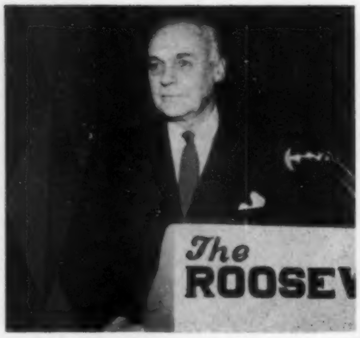
In an effort to encourage early registration the committee has promised a variety of prizes to those who sign up without delay. Details for advance registration will appear in the June issue of MINING ENGINEERING.

Local Section Chairman O. C. Chapman has indicated that Florida's Governor Collins has been approached to address the group. More on that later.



First annual meeting of the Society of Mining Engineers of AIME—the Southeastern States Mining Conference—is to be held October 15 to 18 at Tampa, Fla., site of this loading operation. Program featuring some 45 papers, several field trips, and plentiful social activity is already past the planning stage. ***See you in Tampa!!***

AIME President C. E. Reistle, Jr. receiving proclamation from New Orleans Mayor de Lesseps S. Morrison declaring "AIME Week."



B. Brewster Jennings who was the principal speaker at the All-Institute technical session Tuesday afternoon, discussed oil in the Middle East.

New Orleans Annual

The 1957 renewal of the Annual Meeting held this year at New Orleans set new records for out-of-New York meetings with registration of over 3700, including 900 ladies. The Meeting featured many innovations including the All-Institute Technical Session on Tuesday afternoon and marked the emergence of the three Societies within the Institute; the Society of Mining Engineers, the Metallurgical Society, and the Society of Petroleum Engineers.

Attendance was excellent at both technical sessions and social events, while some of the meetings of the three branches, now societies, taxed New Orleans' capacity to the utmost.

It is to the credit of the Delta Section, sponsoring the meeting and acting as host, that a crowd of this magnitude was handled as smoothly as it was. Activity actually began Friday afternoon with the meeting of the Interim Committee of the Council of Section delegates and continued Saturday and Sunday with delegates' meetings, council meetings, committee meetings, and on Sunday, the general session of the Mineral Industry Education Division. The All-Institute program officially opened at noon on Monday with the traditional welcoming luncheon, whose guests heard Joseph C. Morris, vice president of Tulane University, deliver a concise and clear picture of the accomplishments to be expected for the geophysical year. That evening the social events were started off at the All-Institute cocktail party held at the Jung Hotel. This was followed by the Stag Dinner-Smoker at 7:30 pm that night at the Roosevelt Hotel, which was attended by nearly 1200.

All-Institute Session

As an innovation an All-Institute Technical Session, to be followed by the Institute business meeting, was scheduled for Tuesday afternoon with no conflicting sessions or meetings permitted. The session was unusually well received, attendance

Part of the estimated crowd of 1500 streaming aboard the SS President for the informal dance on Tuesday night.

Joseph C. Morris, vice president of Tulane University, spoke on the Geophysical Year to the welcoming luncheon guests.

Introducing Directors and Officers seated at the head table during the welcoming luncheon in New Orleans.

Meeting Breaks Records

exceeded 1000 as President C. E. Reistle, Jr., started off the meeting with a review of the state of the Institute. The text of President Reistle's remarks may be found on pages 422 to 424 of the April issue. Following President Reistle the guests heard B. Brewster Jennings, chairman of the board, Socony Mobil Oil Co. Inc., speak on *Mankind's Stake in Middle East Oil.* Following Mr. Jennings' review of the situation in this politically troubled vital energy source area, the members attended the annual AIME business meeting which was held in the same room. In addition to a brief summary by the President, each of the staff members delivered his part of the annual report.

Branch Dinners

Tuesday evening each of the branches—Mining, Metallurgy, Petroleum—held its branch dinner, and then the Institute members reconvened on the steamer SS President at 10:00 pm for the All-Institute formal dance. The boat cruised leisurely down the river with over 1500 guests seated on its five decks, in addition to those on the dance floor. The committee had provided entertainment as well as dance music for those who came aboard, and dancing continued after the steamer docked at 1:00 in the morning for those who wished to leave early.

Annual Banquet

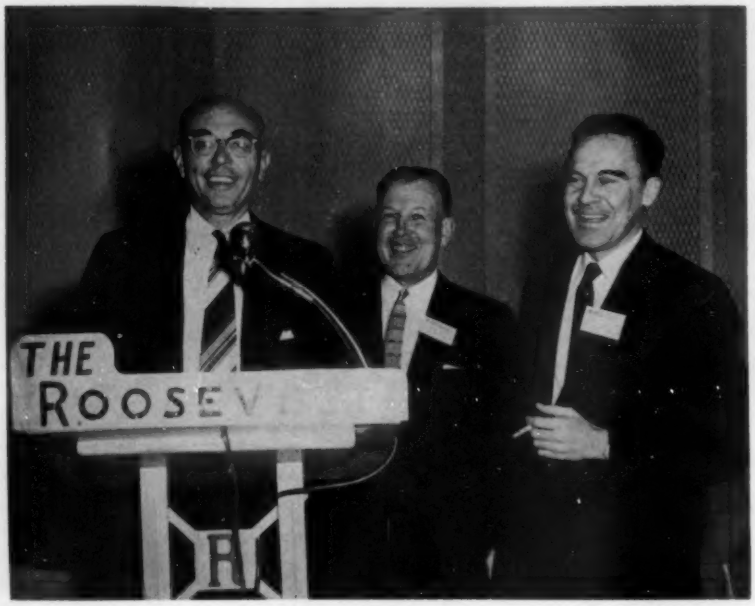
Wednesday evening it was off with the old and on with the new as well as a moment for the profession to honor achievement by top men in its field. President Reistle was chairman and toastmaster of the banquet which presented the Hoover Medal (sponsored by the Four Founder Engineering Societies) to Herbert Hoover, Jr., whose remarks and response to the award presentation may be found on page 511 of this issue. The Alfred Noble prize, also sponsored by the Four Founder Engineering Societies (as well as the Western Society of Engineers) went to Mohamed Mortada. The following five AIME awards were presented at the banquet: the James Douglas Gold Medal to Russel B. Caples; the Anthony F. Lucas Gold Medal to John E. Brantly; the Charles F. Rand Gold Medal to Andrew Fletcher; the Robert H. Richards Award to Antoine M. Gaudin; and the Benjamin F. Fairless Award to Leo F. Reinartz. Following the award presentations, Toastmaster Reistle introduced incoming President Grover J. Holt, who delivered the principal address. Following the banquet the presidential receiving line formed and guests then returned for dancing.

Field Trip

One of the features of this year's Annual Meeting was a scheduling on Friday of extensive field trips, by the Mining group to the Freeport Sulphur Co. operations along the Gulf Coast, and by the Metals group to the Chalmette Works of Kaiser Aluminum & Chemical Corp. With field trips on Friday and the meeting starting on Friday, this year's Annual Meeting was truly more than a week long, and registrants found day-to-day events closely packed despite original limitation on the number of sessions, particularly of concurrent sessions.

John E. Sherborne discussed the challenge to today's petroleum engineering graduates at the MIED general session Sunday evening.

As an experiment, with its innovations, and with its inauguration of the three new Societies, the 1957 Annual Meeting at New Orleans marked the beginning of a new era in AIME history.



Assistant Secretary of the Interior Felix E. Wormser, Society of Mining Engineers President Elmer A. Jones, and Mining Branch Council Chairman Will Mitchell, Jr. appear in fine spirits as they get together at the end of the Mining Branch dinner. Secretary Wormser was the principal speaker of the evening.

Society of Mining Engineers of AIME is Activated at New Orleans — Holds First Board Meeting

In the midst of an active social program and a wide range of technical sessions members of the Mining Branch of AIME were also in the throes of organization and reorganization as the Mining Branch ceased to exist and the new Society of Mining Engineers took hold.

Outgoing Mining Branch Council Chairman, Will Mitchell, Jr., acted as Toastmaster at the last dinner of the Branch, and "buried the Mining Branch" while introducing its successor, the new Society and its new President Elmer A. Jones. Principal speaker at the Mining Branch dinner Tuesday night was the Assistant Secretary of the Interior Felix E. Wormser who enlightened the guests on the role played by government in the mineral industry.

Attendance of Mining Branch functions and sessions and luncheons of the divisions of the Branch was excellent with over 300 attending the dinner and over 250 attending the MGGD luncheon and the MBD Scotch Breakfast.

The MGGD introduced a new approach to technical session programming by scheduling two all MGG sessions on Wednesday, one in the morning, and one in the afternoon.

Head table at the Mining Branch dinner Tuesday evening. Toastmaster Will Mitchell delved into the classics as he deftly "buried the Mining Branch" and introduced the lusty new Society of Mining Engineers of AIME. At the dinner Felix E. Wormser, Assistant Secretary of the Interior, discussed the government's role in mining.

Incoming President Grover J. Holt and Past-President Carl E. Reistle, Jr. congratulate A. M. Gaudin who received the Robert H. Richards Award for his contributions to the art of mineral beneficiation.

Highlight of the all MGG session and business meeting on Wednesday afternoon was the Jackling Lecture by J. L. Gillson who had received the Jackling Plaque at the MGG luncheon on Tuesday. Dr. Panek received the Robert Peele Award at that same luncheon.

MBD maintained its usual high activity with eight sessions (including one joint session) as well as holding its Scotch Breakfast and the Division luncheon. In addition to its technical sessions the Mining Subdivision sponsored field trips to International Salt Co. and Freeport Sulphur Co. as part of its technical program, while the Geology and Geophysics Subdivisions scheduled five sessions.

The Coal Division held five unusually well attended sessions while the Industrial Minerals Division held seven sessions including one joint session.

Other technical sessions of primary interest to Mining members were held by the Mineral Economics Division. A highlight of its activity was the Latin-American session on Wednesday morning.

The first meeting of the Mining Board was held on Thursday morning by which time a large percentage of its committee appointments could already be announced. Also busy with organizational activity was the MGGD which, under its new chairman, Curtis Wilson, is undertaking a review of its internal organization and committee structure with the aim of better service to its members, and at the same time better coordination of its activity with the new Society of Mining Engineers organization.

Technical Session Reports

Mining Subdivision

Southeastern U. S. Mining Session—The first of five papers was presented by C. F. Talbot, who also showed a movie of the Arkansas operations, Magnet Cove Barium Corp. There, barite is mined both by open pit and underground methods, and then concentrated by jigging and flotation.

Erland Johnson, manager of the International Salt Co. mine, Avery Is., La., stated labor costs were cut 35 pct and production capacity trebled when a complete underground conveyor haulage was put into operation. It was made possible by the use of a portable screw-crusher-feeder designed by Freeport Sulphur engineers and built by Joy Mfg. Co.

Three key figures for the mining engineers get-together after the MGGD luncheon. Left to right: new Society President, Elmer A. Jones, incoming MGGD Chairman Curtis L. Wilson, and Institute President Grover J. Holt appear to have more on their minds than the new gavel in Mr. Wilson's hands.

LEFT: Ian Campbell, who made the presentation, and Joseph L. Gillson, 1957 Jackling lecturer display the award plaque following the MGGD luncheon at which the award was presented. Dr. Gillson delivered the Jackling lecture the following afternoon. RIGHT: H. C. Weed long active in mining publications and first chairman of the Editorial Board, and Kenneth W. Cook outgoing MGGD chairman with Lewis A. Panek (center) who received the Robert Peele Memorial Award. The Peele Award for 1957 was based on Dr. Panek's paper *Analysis of Roof Bolting Systems Based on Model Studies* which was published in MINING ENGINEERING October 1955.

The open pit mining and beneficiation problems involved in the East Texas iron ore deposits were illustrated with interesting slides in Vincent Malone's papers on Lone Star Steel's iron mining operations. These low grade, thin, limonite and siderite deposits furnish iron ore for a steel operation now supplying pipe to the oil industry.

L. H. Johnson presented a paper by members of the staff of Tennessee Coal & Iron Mines. Haulage improvements on the 147 mi of underground track in the Alabama mines were based on engineering studies over a period of years and resulted in an increase of 60 pct in capacity while reducing accidents 66 pct.

The last paper took us back to Arkansas when T. M. Howell, manager, Big Rock Stone Material Co., a Minnesota Mining subsidiary, told about his experience with jet drilling in nepheline synenite.—*J. H. Bailey.*

Canadian Mining Session—Four papers were presented at this meeting. Philip Pearson, manager, Caland Ore Co., Ontario, described the dredging program in operation to remove 160 million cu yd of lake bottom material overlying the iron orebody. He showed slides illustrating the dredging process, and a cross section through the orebody.

Neil H. George's paper dealt with safety in the Canadian metal mines from its inception to the present state of organization. He outlined various techniques currently used to prevent accidents.

F. E. Patton, manager, Pamour Porcupine Mines Ltd., described a unique method of backfilling developed and used at Noranda since 1938. The backfill consists of a mixture of granulated reverberatory slag and pyrrhotite oxidizes and forms a consolidated fill of the consistency of weak cement. Thus far 17 million t of this type of fill have been placed, permitting the maximum pillar recovery in wide orebodies under good ground conditions.

The last speaker, C. M. Barrett, mechanical inspector of mines, Province of Ontario, gave a resume of hoisting practice and description of the equipment as used in Canadian mines. More than 700 hoists are now in operation, the larger having a rating up to 9,000 lb driven by 6,000 horsepower motors at a speed of 3,000 ft per min. Friction or Koepe hoisting has entered the field with fifteen on order and three in operation. With continued improvement in equipment, the speaker felt that hoists of the future will be operated with the same ease as self-operated apartment elevators.—*J. L. Ramsell.*

Shaft Sinking—Three papers were presented at the opening session of the Mining Subdivision, and attendance was heavy throughout the morning. C. N. Kravig, Mine Supt. of Homestake's operations at Lead,

The head table at the MGGD luncheon held Tuesday noon. Over 250 attended the luncheon at which the Peele Award and the Jackling Award were presented. Institute President Grover J. Holt spoke briefly on common misconceptions about the Institute.

S. D., led off with a discussion of their experience in driving long pilot raises, up to 900 ft in length, for later stripping to standard shaft size. Operating details were explained, followed by a general discussion which brought out the cost savings over conventional shaft sinking methods resulting from the use of the raising and stripping system, even after allowance for substantial drifting costs.

An outstanding paper on large diameter core drilling was presented by T. N. Williamson. A historical summary of past and present drilling methods was given, followed by a detailed description of the machine developed by co-author Victor Zeni, which has completed seven 6 ft diameter shafts at coal mines in W. Va. Great interest was evidenced and Mr. Williamson answered many questions from the floor.

The final paper was an interesting comparison of the merits of circular concrete shafts as opposed to standard timbered design, presented by T. M. Berry. The many factors affecting a choice were brought out, and the need for careful analysis of the requirements before deciding, was emphasized.—*H. B. Spencer.*

The head table at the Mineral Economics Luncheon. E. H. Robie spoke to the group on progress of the forthcoming volume on Mineral Economics which he is editing and is sponsored by the Division. Left to right: Evan Just, E. H. Robie, Clayton G. Ball, President C. E. Reistle, Jr., and L. C. Raymond.

Geology Subdivision

General Session—This meeting was well attended considering its late position on the convention program. A. E. Granger very nicely summarized the problems involved in administering a staff of geologists during this period of manpower shortage. The human relations side of the job was emphasized. Phillip Eckman's description of Ore Knob was closely followed by many in the audience who are interested in the area. Underground, the structure looks like a drag fold, but finding any surface suggestion of the fold seems impossible in an area of sparse outcrops.

The paper on Marcona, Peru, by W. Bourret and Hayes was given by Wes Bourret. Nearly 3 million tons per year are being produced from a magnetite deposit replacing limestone. The use of dry percussion drills to sample heavy ore in vertical holes as much as 100 meters deep was described. A nice job has been done in outlining orebodies below a layer of wind-blown sand.

A paper by G. J. Anderson and T. M. Han describing the value of cooperation between geologists and ore-dressers was read by Burton Boyum. Ore types were described and their potentialities for concentrate production discussed.—*E. L. Ohle.*

Symposium on Syngenetic Sedimentary Ore Deposits—In this session six papers compared the syngenetic sedimentary ores with ores of controversial origin contained within sedimentary rocks. C. F. Park, Jr. recognizes bedded manganese ores as syngenetic—commonly associated with tuffs or taconite. Bacteria might influence manganese precipitation, but oxygen supply, pH and Eh are important. The last probably causes separation of iron from manganese during sedimentation. J. Royce, J. Osborn, and J. Aase, discussing the sedimentary origin of iron formation, drew attention to intra-formational conglomerates and algal structures.

J. L. Kulp outlined how isotopic ratios of certain elements change during some geological processes thereby providing an insight into an element's history. Age determinations, also, can help distinguish epigenetic from syngenetic deposits. He was followed by J. R. Rand, who concluded that the White Pine deposit in Mich. is syngenetic because lithology alone controls the copper mineralization; faults have no effect.

D. Robertson and N. Steenland discussed the Blind River ores beach concentrates of detrital brannerite and monazite deposited in a northward advancing sea. Preliminary age determinations suggest a presedimentation age for the rounded ore grains.

(Continued on page 573)

Among those at the head table of the Coal Division Luncheon were: seated left to right: J. B. Morrow, Will Mitchell, Jr., C. E. Reistle, Jr., Carl T. Hayden. Back row: C. E. Lawall, M. D. Cooper, H. F. Yancey, E. Steidle, C. T. Holland, H. B. Charmbury, and Arnold Buzzalini.

A Salute to The Men Behind the Scenes—Your Program Chairmen

The diversity, interest, and quality of the 1957 Annual Meeting Mining Program can be attributed to the patience and perseverance of last year's program chairmen. Behind the scenes, these men wrote hundreds of letters to more than 250 authors and session chairmen.

R. P. FULL

MGGD Coordinator—Roy P. Full is a native of Portland, Ore., and attended Pacific University, and Oregon State College, receiving his degree from the University of Idaho in 1942. After completing his studies, Mr. Full accepted a post on the engineering staff of Sunshine Mining Co., Kellogg, Idaho. For several years he was a geologist with the USGS, after which he joined forces with P. J. Shenon to open a consulting firm in Salt Lake City.

MBD—W. B. Stephenson, president of the Allen-Sherman-Hoff Pump Co., is a native of Minneapolis and received his mining engineering degree at Pennsylvania State College. His is a success story with the same company, which he joined after graduation, rising to production department manager, vice president, and finally president. He is 1957 MBD chairman.

W. B. STEPHENSON

Geology—T. Walthier is a native New Yorker and received his B.A., M.A., and Ph.D. degrees at Columbia University. After summer stints as party chief for the Newfoundland Geological Survey and the Labrador Mining & Exploration Co., he became supervising geologist for the Iron Ore Co. of Canada. Mr. Walthier also taught at Brown University and New York University. Later he was staff geologist for the AEC Raw Materials Div., and at present is senior geologist, Bear Creek Mining Co., Morristown, Pa.

Coal—D. R. Mitchell, long the secretary of the Coal Division and widely known industry figure, acted as their program chairman for the 1957 Annual Meeting. Mr. Mitchell is at Pennsylvania State University, University Park, Pa.

IndMD—T. E. Gillingham hails from Oxford, Pa., and is a graduate of Harvard University. Subsequently, he studied at the Universities of Arizona and Minnesota. Mr. Gillingham's first post was with Nielson & Co. Inc. in the Philippines. Since 1954 he has been district geologist with Bear Creek Mining Co.

A. W. SCHLECHTEN

MED—A. W. Schlechten, professor and chairman, Dept. of Metallurgical Engineering, Missouri School of Mines at Rolla, is a native of Bozeman, Mont. He graduated from the Montana School of Mines and received his doctorate at MIT. Prof. Schlechten has taught at the University of Minnesota, Oregon State College, and also worked as research engineer for Anaconda Co. Active in AIME, he has been chairman of the following: EMD, Education Committee of MBD, St. Louis Section, and MIED program committee. Editorial advisor on mining and metallurgy for the Encyclopedia Britannica, Prof. Schlechten was chosen as U. S. representative on a European economic mission for OEEC. In 1953 ASM awarded him a certificate and $2000 for "outstanding teaching of metallurgy."

C. WILSON

Mining—Clark Wilson, president and director of Utah Mining Assn., is a graduate of the University of Utah and also attended the University of Arizona which awarded him an M.S. degree in geology in 1938. At present he is vice president and director of the following companies: New Park Mining Co. and Northwest Uranium Mines Inc., and director of East Utah Mining Co. and Treasure Uranium Resources Inc. Active AIME member Mr. Wilson has served as Utah Section Chairman, national secretary, on the Council of Section Delegates, member of the Saunders Gold Medal Committee, and is the 1957 MGGD Chairman.

Geophysics—R. J. Lacy, chief geophysicist for American Smelting & Refining Co., Salt Lake City, is a graduate of the University of Minnesota. After receiving his mining engineering degree in 1937, Mr. Lacy became a mine geologist for The Anaconda Co. in Butte, Mont. In 1946 he joined the California Co. as

R. J. LACY

a geological observer on exploration parties. He returned to his alma mater in 1947 for postgraduate work, accepting a post as geologist with Asarco the following year.

(Continued on page 579)

(Continued from page 571)

The last speaker, George Bain, emphasized that ore distribution within a sedimentary rock distinguishes epigenetic from syngenetic mineralization. Sedimentary features localize both types, but in epigenetic ores, tectonic features distort this sedimentary control. Thus, the Witwatersrand, the Blind River and the Colorado Plateau ores are syngenetic; the Rhodesian copper-cobalt deposits are epigenetic.—*T. Walthier.*

Latin American Session—Geology— The wide variety of ore types at Anaconda's Chuquicamata mine in Chile, necessitates close correlation between careful geological mapping of the benches, correlation of drilling and assay data, predictions of ore types, and planning of mining operations. Glenn C. Waterman illustrated how accurate and detailed recording of geological data is essential to efficient pit operation.

In 1948 the Peruvian Government presented a new mining code which served to stimulate exploration and development of the mineral resources of that country by foreign capital. Three of the papers presented reflect the stimulus of this legislation. The Toquepala porphyry copper deposit under development by the Southern Peru Copper Corp. was described by J. H. Courtright; and its sister deposit at Cuajone, by W. C. Lacy. Cerro de Pasco Corp. has been successful in exploration of contact metasomatic deposits in the Peruvian Cordillera. Much of this success can be attributed to an understanding of factors of ore localization. Alberto Terrones illustrated the nature of structural control in these deposits.

Lead deposits in Northeastern Mexico appear to be frequently localized within a distinctive limestone horizon in the Cretaceous. P. Sanchez Mejorada pointed out the possibilities of using this favorable horizon to guide exploration work.—*W. C. Lacy.*

MED Reports

General Session—Optimistic forecasts on the future use of metals and coal were highlighted in this session. The papers dealt with the substantial demand for metal products in undeveloped countries, and for coal in industrialized countries. Technical details of pumping gilsonite, a soft pitch-like solid, through 72 miles of pipeline, stimulated many interested questions. The provocative query *Are We Overlooking Tungsten?* brought forth a reasoned analysis of the use of more tungsten in alloys for jet propulsion turbines. An animated discussion on the merits of other metals followed.—*C. G. Ball.*

Industrial Minerals Division

Ceramic Raw Materials—Attendance, which often involved standing room

The 1956 President greets the 1953 President as C. E. Reistle, Jr. congratulates Andrew Fletcher as the 1957 recipient of the C. F. Rand Gold Medal for distinguished administration in nonferrous mining and metallurgical enterprises.

only, was testimony to the wide interest aroused by the topics. To fully appreciate this, it should be noted that word had gotten around that this room was something of a "black hole" space-wise. Nevertheless, the speakers and topics packed them in.

The keynote speech was E. W. Summers' discussion of the use and purpose of alumina in glass, which increases the chemical durability of the glass. Alumina serves to depress the liquids, but also increases the viscosity, which can be offset by introduction of soda. Two sample calculations illustrated how costs of the components, from different raw material sources, may be determined.

In the following paper, Carroll Rogers, Jr. pointed out why the glass industry has come to prefer flotation feldspar. Of the 250,000 tons used annually 90 pct are floated. The favorable factors are uniformity of product, low iron content, abundant supply, and decreasing costs. In 1933 feldspar sold for $33 per ton; today it sells for $12 per ton.

The next paper, by H. B. DuBois traced the history of feldspar mining from initial operations by Indians in N. C., to the present. Hand picking, froth flotation, and a new dry process employing both electrostatic and magnetic separation, now in operation in N. H. and Quebec, were described. It was brought out that feldspar with a higher K_2O content produces glass products with a better tone; the higher the Na_2O content, the lower the fluxing point. H. R. Deeth followed with a discussion of nepheline syenite as a source of alumina and alkalies. In the principal producing area, Lakefield, Ont., millions of tons of this material are available. Despite some minerallogical variation, the chemical composition is notably uniform. The speaker referred briefly to other views, as to the origin of this unusual rock, but took a clearly promagmatist position.

Virginia aplite, another unusual source of alumina, was described by V. V. Kelsey. The alumina content averages 23.5 pct and although Fe_2O_3 is somewhat higher than in other raw materials, the aplite can be used for window glass, opal and amber glasses. Appropriately, in the concluding paper of the session, R. W. Hopkins, looking into the future, suggested possible new sources of alumina. One developed within the current decade, is blast furnace slag with the trade name, Calumite. Today, this is used for 50 pct of the amber glass produced in this country. Dune sands of high feldspar content offer a possibility for a new source. Perlite, bauxite, kaolin clays, kyanite, topaz, cryolite and anorthite were mentioned in the list of future possibilities.—*Ian Campbell.*

Dry Separation—The papers presented at this session dealt with both the basic fundamental aspects and certain practical applications of electrostatics for dry separation of minerals. With respect to the former, a strong case was made for extending fundamental investigations of the mechanisms involved if its full utility is to be realized. It was further suggested that the recent advances by solid-state physicists in the transistor field might well provide some background for fruitful investigation in the minerals beneficiation field.

Several interesting examples of the application of the art of electrostatic separation were provided by the other papers. The procedures and equipment used were well described, and the extent of the concentration effected for each application were clearly defined. The papers pointed out that in these applications, electrostatics was a new tool

A lull in the activity at the Scotch breakfast Tuesday morning provides head table guests with an opportunity to exchange ideas—and stories.

for performing special and essential process steps and not just an alternate for available and acceptable methods and equipment.

The nature of the questions from the floor, following the papers, indicated that the experience described by the authors will stimulate a number of those who attended to explore the potential of electrostatic for specific problems of their own.—*C. W. Hedberg.*

The record breaking attendance and varied entertainment marked the renewal of the Scotch breakfast at New Orleans. N. L. Weiss outgoing chairman of the Division and Grover J. Holt incoming AIME President can be identified among those at the head table on Tuesday morning.

Ultra-Lightweight Aggregates—Thomas B. Shufflebarger, Jr. summarized the geology of occurrences of expandable shale and clays in the Southeastern U. S. These range in age from pre-cambrian to recent, and are wide-spread geographically over the Southeast. The prospect for greater industrial utilization of these materials appears to be good. Discussion brought out the fact that lightweight aggregate made from shale and clay in the Southeast does not have the objectionable tendency to produce "popouts" which is characteristic of some of the Western materials which contain caliche.

R. S. Funk, of the Perlite Institute, described the fast-growing perlite industry and presented a sound-movie showing the mining and processing of perlite.

H. H. Russell detailed the industrial uses of fly ash, with emphasis on its utilization in highway construction programs, especially in the road base, according to a road base design developed through efforts of Bituminous Coal Research Inc. It was stated that fly ash is somewhat heavier than perlite.

J. A. Kelley discussed the occurrence, technology and end uses of vermiculite. Samples of a wide variety of products made from vermiculite, or using vermiculite in their composition, were shown. These products, ranging from lightweight glazed tile to rail-joint compound, attracted much attention. —*B. F. Buie.*

Chemical Raw Materials—This session was well attended. Over 100 people were seated and many were turned away for lack of space. Warren R. Wagner gave an interesting paper on Euxenite as a new chemical raw material, and described the deposits; as well as the mining, beneficiation, and extractive techniques. Eugene Callaghan contributed to the barite industry in describing the geology of barite deposits in New Mexico and their present utilization.

Highlights of the lithium industry, with pertinent comments on its future were offered by P. E. Landolt. The unique problems of salt exploration and methods of overcoming them, together with mining and milling processes at the Detroit mine were described by C. H. Jacoby. K. C. Li explained processes for making titanium and zirconium, and their advantages and limitations. He discussed costs, raw materials, and uses, and gave his opinion as to the trend of development.—*R. S. Shrode.*

Part of the lively crowd at the Scotch breakfast. Songs, entertainment, and Don Scott's traditional reading of Scotch verses accomplish whatever the busy chefs might have left undone.

Mineral Aggregates and Dimension Stone—An interested group attended the session on mineral aggregates and dimension stone, to hear three papers on production and testing of stone, and two papers on its use. A new mobile drill and improved drilling pattern has given better fragmentation, increased production, and reduced costs for a Ga. granite producer. A granite quarry in Mass. is trying to reduce unusable stone with resistance wire strain gages to predict steps in the bottom planes of quarried blocks; the method is promising. A new test method, measuring length change after freezing and thawing of short drilled cores of ledge rock, gives better predictions

Two views of the Industrial Minerals Division luncheon head table. Left, AIME President-Elect Augustus Kinzel spoke briefly on Institute business to the group. Right, guest speaker Z. W. Bartlett, Freeport Sulphur Co.

of the durability of stone than the classical sodium and magnesium sulfate tests. Studies made at the Waterways Experiment Station show that stone sand made from limestone or traprock can extend cement grouts such as are used to reduce the permeability of foundations of dams. The amount of stone sand that can be used is appreciably greater where a relatively large proportion of it is finer than No. 100 sieve. The session ended with a broad view of the complex geology of Northern Calif., as it affects aggregate production. A lively discussion of all papers followed.—*Katharine Mather.*

MBD Reports

Mill Design—The attendance at this session was between 140 and 200. In the absence of chairman O. W. Walvoord, who was unable to come to New Orleans, the meeting was conducted by Warren L. Howes, assisted by E. H. Crabtree. Four excellent papers were presented: *Soil Studies for Foundations* by E. H. Bronson; *Electrical Mill Design* by C. B. Risler and W. E. Thomas; *Mill Operating Record and Accounts* by N. Herz; and *Factors to Consider in Vibrating Screen Installations* by N. Kuenhold. Discussion was devoted to practical limits of fine screen sizing in connection with Mr. Kuenhold's paper. —*W. L. Howes.*

Solids-Fluids Separation & Solution and Precipitation—A new tool in minerals beneficiation is the Rotobelt filter, consisting of an endless belt which continuously removes the filter media from the drum for cake discharge and washing of the filter media. Several examples were given in the metallurgical field to show its application.

The remainder of the session was concentrated on the field of solvent extraction which has become so prominent recently. In two papers, *Recovery of Uranium from Uraniferous Lignites*, and *Some New Solvent Extraction Processes for Use in Hydrometallurgical Treatment of U, TH, and V Ores*, emphasis was placed upon the new application of solvent extraction. The information indicated that solvent extraction will find many applications to the recovery of relatively pure concentrates from low grade ores.

An excellent paper on *Solvent Extraction of Uranium at Ship Rock* by W. C. Hazen, yielded excellent operating data and some cost information on a recently installed plant. Better results were obtained than had been anticipated. Finally, the field of solvent extraction of U from phosphate slimes illustrated the application in this field. Without solvent extraction the process could not have been successful. This is particularly interesting due to the extremely low concentration of U in the raw material.—*D. A. Dahlstrom.*

Crushing and Grinding—Approximately 200 members and non-members were present on Monday afternoon. The opening paper, *Grinding Practice at Tennessee Copper Co.'s*

H. DeWitt Smith congratulates Herbert Hoover, Jr. who received the Hoover Medal sponsored by the Four Founder Societies, and named for his father former President Hoover. The former President of the U. S. was the first recipient of the Medal in 1930 and is the senior Past-President of the Institute. Mr. Hoover's response on receipt of the medal at the annual banquet appears on page 511 of this issue.

Isabella Mill, presented by F. M. Lewis, Sr., discussed the large slow speed ball mill and hydraulic classifier which has improved grinding efficiency and lowered operating costs at the mill.

The second paper, *Comminution Exposure Constant by the Third Theory*, was presented by F. C. Bond, and covered a new natural size distribution exponential equation relating the particle size to the third theory work input, and defined the work size relationship.

The third paper, *Rod Mill Experience in Grinding Taconite Ore at Reserve Mining Co.*, was presented by E. M. Furness, and covered various changes in the operation of the rod mill at the Babbitt plant of Reserve Mining Co. The result of the work at Babbitt led to the selection of 10 in. x 16 in. rod mills at the E. W. Davis Works plant.

R. J. Charles gave the final paper, *Energy-Size Reduction Relationships in Comminution*. This paper examined a method by which the general differential equation relating energy input and size reduction could be used to predict product size analysis from comminution process.—*D. J. Drinkwater.*

Concentration—This session which followed the MBD Luncheon on Thursday, featured an address by A. M. Gaudin, Richards Award winner who discussed the broadening scope of minerals beneficiation and the increased use of unit operations in separating components of minerals. He concluded that the term mineral engineering would best describe the field, and added that unwavering teamwork is necessary to obtain the best combination of processes in the treatment of ores.

C. L. Sollenberger followed with a presentation on the influence of the soda to silica ratio on the effectiveness of sodium silicate as a gangue depressant.

A. W. Last described the leach-precipitation-flotation process to be used at the Ray Mines Div., of Kennecott Copper Corp. This unique application of unit processes in the treatment of semi-oxidized copper ores was given in detail.

The next speaker was M. F. McCarthy who discussed the use of Separan 2610[R] to improve thickening, filtration, and clarification. The usual thickening and filtration tests with Separan might be misleading, and modified tests are desirable. Characteristics of the reagent suggest unique application and handling methods.

The concluding speaker, H. K. Martin, described the performance of equipment and process at the Lavender Pit Concentrator. An interesting application of existing equipment in this new plant was explained, as well as the use of cyclones in the regrinding circuit to obtain additional classification.—*F. J. Windolph.*

Coal Division

Washing—The convertol process for cleaning coal by agglomerating with oil was described by A. H. Brisse. Using less oil than the Trent process, it offers good prospects of commercial utilization in this country. H. F. Yancey presented a very interesting paper indicating that the increase of viscosity due to clay in a heavy medium coal washer can cause a serious loss of coal unexpected, considering the specific gravity of the suspension.

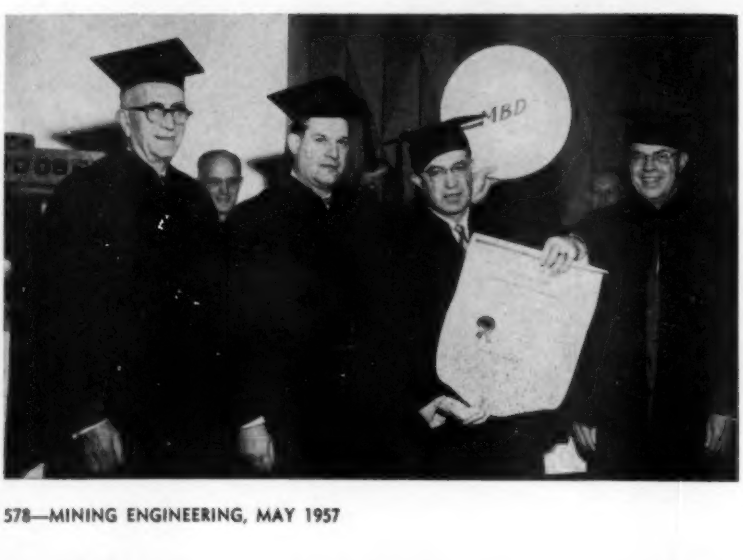
D. H. Davis depicted the Chance cone operation at the Mathies mine with the modifications in construction and operation to improve performance. This was followed by a detailed study of the effect on recovery of coal by selection of pure hydrogen flotation reagents by D. Mitchell and S. Sun. In addition to pointing out the usual variation of reagent concentration, the work demonstrated the effect of increasing length of the hydrocarbon chain, varying position of double bonds, location and length of side chains, and the effects of ring compounds compared with chains of the same number of atoms The work explains variations in effectiveness of commercial hydrocarbon collectors.

In the last paper, E. H. Citron described a newly-developed piston jig using an artificial bed of rock

Missouri School of Mines sent a large student delegation to the Annual Meeting. The group is pictured here some 50 strong together with three of the faculty members, and totaled 57 in all.

At the MBD luncheon Thursday noon, Norman L. Weiss (seated), guest speaker J. Gordon Parr, and incoming Division chairman W. B. Stephenson. Professor Parr's topic was *People, Petunias, and Pyrite*—and the substance of his talk could only have disappointed those who lack any imagination.

Scene aboard the SS President which cruised up and down the Mississippi during the informal dance on Tuesday evening. The dance committee provided not only music but entertainment for the over 1500 guests aboard.



At the MBD luncheon the mill *gentlemen of distinction* added Norman L. Weiss to their distinguished roster—but not until Norm had had to give as good as he got in a difficult examination.

from the washing plant refuse.—*E. M. Spokes.*

Dust Collection and Drying—Three papers were presented at this meeting. *Dust Collection with the Microdyne* was read by author A. Lee Barrett. It referred to outside and simple applications in addition to the practicality for "at the face" operations. The size of the unit is good for horizontal or vertical applications. No expensive housing is required. Test work with temperatures such as in fly ash applications is unknown as yet. Some problems remain but apparent and comparative percentage efficiencies look good.

Other papers presented were: *Thermal Drying Costs for Fine Coal* by H. Washburn and G. L. Judy; and *Combined Air Cleaning and Heat Drying of Coal* by F. P. Calhoun.—*J. W. Woomer.*

MIED

General Session—This meeting on Sunday afternoon broke all attendance records for MIED sessions. The theme was *Empirical versus Basic Courses for Practicing Engineers.* Both sides of the question were capably presented by Lute J. Parkinson, A. R. Spalding, and George K. Dreher. A lively discussion period followed the reading of these papers and numerous viewpoints of this question were aired.

A very interesting paper on the education of metallurgical engineers in the Soviet Union was offered by J. P. Nielsen. He recently visited Russia where he observed the technical education program. Mr. Nielsen reported that these engineers usually specialize in some specific phase or branch of the metallurgical field. The flood of questions which ensued could not all be answered because time did not permit.—*K. S. Stout.*

Directory

A new all-Institute directory was announced in the April issue. Copies of the directory may be obtained by using the coupon which appeared on page 478, Mining Engineering, April 1957.

Program Chairmen

(Continued from page 572)

MED—F. R. Dykstra is a graduate of the University of Wisconsin, where he received his B.A. degree, continuing his studies at Columbia University which awarded him an M.A. in economic geology in 1947. After a year as geologist with H. A. Brassert & Co., New York, Mr. Dykstra joined E. J. Lavino & Co., Philadelphia, in the capacity of assistant to the vice president.

ENGINEER*

"EJC's Report on What's Happening in Engineering"

*A Periodic Newsletter from Engineers Joint Council • 29 W. 39th Street, New York 18, N. Y.

EJC Salary Survey

Just published, the EJC report on engineers salary structure for 1956 covers 107,000 engineering graduates; 93,000 in industry, 10,000 in government; and 4,000 in education. Most complete to date, survey relates earnings to graduation year of B.S.'s with special tables for Ph.D.'s. Tables show earning scales in 13 major employment areas such as chemicals and allied products, and public utilities. Government engineers divided into state and federal service, and engineers in education, show teaching income and outside income. The report, entitled *Professional Income of Engineers*, is available at EJC, 29 W. 39th St., New York 18, N. Y. The 36-page printed booklet complete with tables and graphs costs $1.50 per copy.

Speakers Bureau

To meet demand by industry and lay groups for authorities in broad areas such as manpower, employment conditions, etc., EJC is informally expediting formation of panels and securing individual speakers for functions outside of EJC. Now extremely limited by own manpower shortage, EJC secretariat hopes to expand activity. Inquiries for speakers or local level cooperative programs are welcomed.

Welcome, New Members

The Society of American Military Engineers and the American Institute of Consulting Engineers became, respectively, constituent and associate societies, as of Jan. 16, 1957.

General Assembly

Important ideas from 1957 EJC Assembly: Engineers' salaries have not kept pace with rising national economy, productivity, and labor wages; merit rating and position evaluation advanced as means of salary administration; engineering manpower, a defense bottleneck; government taking new look at employed engineers salary-wise; overseas opportunities are vast. These and more in EJC Assembly proceedings available about March 15 at EJC, 29 West 39th St., New York 18, N. Y. Report includes papers of national experts and floor discussions; price—$1.00 each copy.

ECPD-EJC

Joint meeting of executive committees of both organizations propose closer cooperation. EJC participates in ECPD's annual meeting in October 1957 and ECPD may participate in the 1958 General Assembly of EJC.

Washington Eye

EJC staff assigned task of frequent check on developing trends in Executive and Legislative branches of Federal Government, in which engineering profession may have interest. Purpose: to transmit information to you through EJC.

Utah Section Scores Howling Success With Miners' Revue

When the Utah Section held a joint dinner-meeting with the Woman's Auxiliary on Feb. 16, 1947, a hilarious time was had by all. The meeting, which replaced the regular monthly Section get-together, featured a seven-act show, the Miners' Revue, with talent recruited from the Utah Section.

Above, the distaff contribution, a Can-Can dance, added to the general gaiety. Displaying their terpsichorean talent are, left to right, Miss Jane Hughes, Mrs. H. Buchman, Mrs. K. F. Eilers, and Mrs. J. P. O'Keefe.

The Newhouse Hotel was the scene of the festivities, beginning with a cocktail party at 6:30 pm. After the proper amount of indulgence by all those present, dinner was served at 8 pm.

The entertainment, which commenced at 9 pm, was planned, written, directed, and performed by members of the Section. A duet by two Auxiliary members opened the program, followed by a chorus of 18 bass and soprano voices. One of the evening's highlights was a Can-Can dance by the female contingent. They were accompanied by Section chairman Dan McElhattan, who did his vocal number in pantomime.

A double Barber Shop Quartette were on next, followed by a distaff offering, entitled *The Perfect Solution* or *Leave it to the Girls*. This skit was about a recent visit to an underground mine.

A show-stopper was the comedy routine starring Glen Burt and P. H. Ensign whose comedy act was called *Tweedy Bird and Tom Cat*. For the grande finale, the entire cast sang in chorus, which must have inspired the audience of 466 to join in the community songfest afterward. Dancing began about 10 pm, continuing until the last guest left at 1:30 am.

The tremendous *howling* success of the program is largely due to the high percentage of section participation. At least 10 pct of the members actually helped plan the affair. Many thanks should be extended to all the committee members for their work, particularly to WAAIME Chairman, Mrs. W. G. Rouillard; Mrs. J. C. Landenberger, Jr., and Mrs. R. F. Willey; and Messrs. A. G. Kirkland, Raymond Thompson, C. C. Hilton, and R. C. Cole.

Below, a scene from the WAAIME's skit, *The Perfect Solution, or Leave it to the Girls,* shows first aid being applied during an underground mine tour. Front row, Mrs. F. V. Richard and Mrs. Roland Mulchay; back row, Mrs. D. P. Wheeler, Jr. and Mrs. R. E. O'Brien.

Everyone joined in the fun when the Utah Section held its Annual Miners' Revue with the WAAIME. Photographed during their parodying performance are left to right, R. C. Cole, Mrs. R. Willey as Miss Use; A. G. Kirkland; and Mrs. J. C. Landenberger, Jr., as Miss Spent.

Society of Mining Engineers

PERSONALS

D. H. Mode has transferred from Panel Mine, Elliott Lake, Ont., Canada to Lake Cinch Mines Ltd., Uranium City, Saskatchewan.

John A. Key has terminated his association with Key Thompson Development Co. Inc. and is presently residing in Belton, Miss.

Howard Steidle has resigned his position as executive engineer and assistant to the president, Philadelphia and Reading Coal & Iron Co., to become manager of the Business Diversification Dept., Lukens Steel Co., Coatesville, Pa.

G. E. Campbell is with the South Peru Copper Corp., Tacua, Peru.

Samuel L. Coddington has left Cases Industriales de Venezuela, Caracas, for a position as metallurgical engineer with Metales Industriales de Venezuela, in the same city.

Julian Kennedy, III, is with Cerro de Pasco Corp. at Mahr Tunnel, Peru.

Burton Amontree recently joined Cía Minera de Guatemala, Guatemala City.

William S. Adams is now with Maritimes Mining Co., Tilt Cove, Newfoundland.

Halfdan S. Jacobsen is associated with Atlas Copco Canada Ltd. at the Montreal Airport, Quebec.

Bruce R. Pickering, formerly Inspector of Mines, Tanganyika, East Africa, is at Tua Marina, Marlborough, New Zealand.

D. M. Checkley has become general manager, Industrial Engineering Div., Arthur G. McKee & Co., Cleveland.

W. F. Keyes is in Havana, Cuba, on reassignment by the U. S. Bureau of Mines.

W. G. Didrichsen has joined Joy Manufacturing Co., San Francisco.

Robert D. Lowe is mine engineer, United Clay Mines Corp., Gleason, Tenn.

Alonzo M. Wells has accepted a position as evaluation engineer with the Bureau of Land Management, Los Angeles.

John P. Lowe, formerly mining engineer, Haile Mines Inc., New York, has joined Southwestern Engineering Co., Los Angeles.

Harry F. Haller, formerly with Columbia Southern Chemical Corp., Barberton, Ohio, is now associated with Snyder Mining Co., Chisholm, Minn.

(Continued on page 585)

METALS for Today and Tomorrow

REGIONAL REACTIVE METALS CONFERENCE

Ambassador Hotel, Los Angeles, May 28-29, 1957

The Southern California Section of the American Institute of Mining, Metallurgical, and Petroleum Engineers is planning the Second Reactive Metals Conference to be held at the Ambassador Hotel, Los Angeles, California, on May 28 and 29, 1957.

The conference will be concerned with the resources, production, fabrication, properties, and use of such metals as:

Beryllium	Lanthanum	Titanium
Boron	Molybdenum	Thorium
Cerium	Potassium	Tungsten
Columbium	Rhenium	Uranium
Gadolinium	Sodium	Vanadium
Hafnium	Tantalum	Zirconium

Exhibits by a number of prominent companies will show equipment important in the mining and processing of of reactive metals as well as examples of fabrication techniques and fabricated parts of these metals.

The Metals and Mining Branches will hold concurrent meetings on the first day and joint meetings on the second. Tentative program arrangements are as follows:

On the morning of Tuesday, May 28, there will be a Mining session on raw materials resources and exploration, with papers on world potash resources, borate exploration, and uranium exploration. Concurrent Metals session will center on the metallurgy of titanium, zirconium, and hafnium, and will include a paper on casting of titanium. A talk of special interest is being arranged by the Mining Branch for the luncheon, Tuesday noon.

The Tuesday afternoon Metals session will concern fabrication techniques for reactive metals, including vacuum melting, extrusion, and forging, welding, and powder metallurgy. *The afternoon Mining session* will cover mining operations for tungsten, molybdenum, potash, and rare earths. The *dinner on the evening of May 28* will feature James Boyd, former Director of the Bureau of Mines and now Vice President of Kennecott Copper Corporation. He will discuss "The Effect of the Location of Reactive Metal Resources on the Industrial Development of the United States."

The Joint Mining and Metals Session in the morning of May 29 will include papers on beneficiation, refining, and future trends in thorium, alkaline metals, and titanium electrometallurgy, as well as at least one other subject. Bruce S. Old, President of Nuclear Metals, will speak on "Current Interests in Reactive Metals" at the Wednesday luncheon. The *Wednesday afternoon Joint technical session* will include talks on the metallurgy of vanadium, on mechanical working of arc-cast molybdenum alloys, on beryllium, and on niobium, and tantalum.

Registration fee is $3 for AIME members and $5 for nonmembers; students will be admitted free. It is not planned to publish proceedings of the Conference. Where available, reprints of talks will be distributed to registrants.

Further information about the conference can be obtained from Benjamin S. Mesick, General Chairman, A.D. Little Inc., 727 West 7th Street, Los Angeles 17, California.

Personals

(Continued from page 583)

Reese E. Mallette, recently separated from active military duty, has accepted an appointment as instructor, Dept. of Engineering Drawing, College of Engineering, University of Alabama, Birmingham.

Ken Nobs has been transferred to Moab, Utah, from Grand Junction, Colo., by Hidden Splendor Mining Co.

C. A. O'Connell was recently promoted to manager of Mufulira Copper Mines Ltd., Mufulira, Northern Rhodesia. He had been assistant manager.

William S. Eddelman, Jr., is with the Bureau of Indian Affairs, Gallup, N. M.

James J. Scott has accepted an instructorship in mining and petroleum engineering at the University of Wisconsin, where he will complete the requirements for his M.S. degree. Prior to the appointment, he had been mine foreman, Bethlehem Cornwall Corp., Cornwall, Pa.

Robert M. Mahan has resigned his position as general superintendent, Baguio Gold Mining Co., Baguio, P. I., and is in Nelson, B. C., Canada.

Michael J. Messel has left The Ruberoid Co., Hyde Park, Vt., where he was general superintendent, to become general manager, Lake Asbestos of Quebec Ltd., Black Lake, Que., Canada.

Bernard A. Moser, former designing engineer at Wilferd L. Roller Co., has opened a private practice as consulting engineer.

Roger L. Tenney is employed by Braden Copper Co., Sewell, Chile, as assistant chief mining engineer.

Philip R. Merriss has left the staff of the Nickel Processing Corp. of New York to join Alcoa Exploration Co., Ciudad Trujillo, Dominican Republic.

Michael A. Burke is general manager for Minas de Acebo, the Mexican division of Holly Minerals Corp. in Hermosillo, Son., Mexico.

Charles D. Thompson has completed his military service and is now with the McDowell Co. Inc., Cleveland, in their Dwight-Lloyd Div.

D. T. Mitchell has left Emperor Gold Mining Co. Ltd., Vatukoula, Fiji Islands, where he was general manager, and is now manager, Cobar Mines Pty. Ltd., Cobar, Australia.

A. H. Kapadia has transferred from La Luz Mines Ltd., Nicaragua, to Mauricio Hochschild & Cía Ltda., S. A., Chile, where he holds the position of exploration engineer.

(Continued on page 586)

Personals

(Continued from page 585)

Robert Goldsmith has taken a job with Can Erin Mines Ltd., Cork, Ireland.

F. W. Parrott has joined the Explosives Dept. of E. I. Du Pont de Nemours Co. Inc., Wilmington, Del.

Maurice Gratacap, former chief technical advisor to the Eti-Bank, Ankara, Turkey, and consulting engineer to the Venezuelan government, has been appointed technical consultant, Ministry of Mines and Petroleum, La Paz, Bolivia. A graduate of the National School of Mines in Paris, France, Mr. Gratacap's activities have included a wide range of missions in Europe and South America. Prior to accepting his new post, he was an economist and consulting engineer to the Banque de L'Indochine assigned to the appraisal and financial reorganization of industries in Africa.

M. GRATACAP

Victor Oppenheim and **Glenn O. Briscoe**, consultants on Central and South American mineral and petroleum explorations, have recently opened offices in Dallas.

Salisbury Adams, secretary and general counsel for Lithium Corp. of America Inc., is with the company on a full-time basis. Mr. Adams, a graduate of the University of Minnesota and alumnus of Harvard Law School, was previously associated with the law firm of Best, Flanagan, Lewis, Simonet and Bellows.

E. H. Brinley is doing exploration work for the northern Ontario and Manitoba operations of The Anaconda Co. (Canada) Ltd., with headquarters in Port Arthur, Ont.

Luis H. Aguirre is with Worden Jewelry Co., Norton, Kan.

J. J. Reiff is raw materials engineer with the Columbia Iron Mining Co., Provo, Utah. He was formerly employed by the Lone Star Steel Co., Lone Star, Texas, as a geologist.

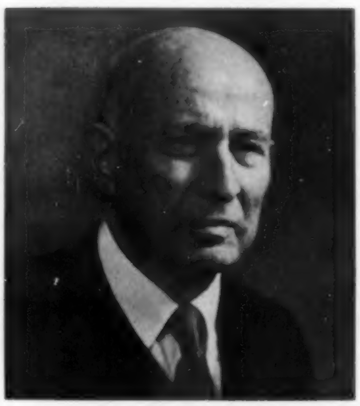
H. R. SPEDDEN

H. Rush Spedden, secretary-treasurer of MBD, and vice president of the Niagara Frontier Section, has been named Director of Research at Union Carbide Ore Co.'s research center, Sterling Forest, N. Y. His duties will include work in geophysics and geochemistry as well as geology, mineralogy and mineral prospecting. Since 1952, Mr. Spedden has had charge of the Minerals Research Dept., Electro Metallurgical Co., Niagara Falls, N. Y.

J. H. Jensen has been designated manager of plant engineering at the Trona Plant, American Potash & Chemical Corp., Trona, Calif.

F. M. NELSON

Texas Gulf Sulphur Co. has announced the following changes: **Claude O. Stephens** has been elected president, succeeding **Fred M. Nelson**, who becomes chairman and will continue as chief executive officer. Mr. Stephens has served as vice president and general manager of production since 1954. **Walter H. Aldridge**, chairman since 1951, has been named chairman emeritus, and will continue as a director.



W. A. ALDRICH

George W. Rust, formerly senior geologist with Bear Creek Mining Co., N. J., has joined Pacific Coast Co. as director of mining and exploration. His headquarters will be in San Francisco.

W. Jewitt has left Rix Athabasca Uranium Mines Ltd., Sask., Canada, to join Gullbridge Mines Ltd., Newfoundland.

John S. Newton has become vice president of Goodman Manufacturing Co., Chicago.

T. M. Eisner has joined Chile Exploration Co., Chuquicamata, subsidiary of The Anaconda Co.

Hugh Wright, consulting mining engineer for the Texas Gulf Sulphur Co., New York, recently retired after 33 years of service.

OBITUARIES

Hoken E. Nyberg (Member 1919) died on Oct. 18, 1956 in Seattle. Born in Pueblo, Colo., in 1879, Mr. Nyberg graduated from the Colorado School of Mines in 1906. He began his career in mining as a millman for American Smelting & Refining Co. in his home town. Mr. Nyberg held various positions in the years that followed, becoming surveyor, chief engineer, and finally general superintendent of Las Dos Estrellas Mining Co., Mexico, before his retirement.

Elmer A. Holbrook (Member 1908) died on Feb. 20, 1957, in Pittsburgh. A former AIME Director (1945-1946) the 76-year-old retired Dean of the University of Pittsburgh Schools of Engineering & Mines, had been suffering from a heart condition. He had served as dean from 1927 until his retirement in 1950. Dr. Holbrook was the first recipient of AIME's MIED Award last year. Born in Fitchburg, Mass., he earned his degree at Massachusetts Institute of Technology, and was presented with an honorary doctorate degree by the University of Illinois. He is the author of more than 100 technical articles on mining and engineering education.

M. I. Signer (Member 1939) died on Nov. 17, 1956. Dean of Faculty at Colorado School of Mines, Golden, Colo., he was born in Tonica, Ill. in 1900, and received his B. S. degree from the Missouri School of Mines in 1922. Mr. Signer's first position was with the Princeton Gold Mines Co. in Mt. Bullion, Calif. In 1923 he became resident engineer, Illinois Div. of Highways in Ottawa. He began his career in the academic world in 1929 as instructor at Colorado School of Mines, and later became assistant professor of mining there.

John L. Rich (Member 1920) geology professor at the University of Cincinnati, died recently. A native of Hobart, N. Y., where he was born Dec. 1, 1884, Dr. Rich did his undergraduate work at Cornell University where he also received a Ph.D. in 1911. Prior to his teaching work, Dr. Rich was associated with the USGS in Louisiana, Illinois, and New York. He also worked as a geologist for Richmond Levering & Co,. New York, and Argus Oil Co. in Kansas.

W. A. Rigby (Member 1916) died on Jan. 19, 1957. Born in Mason City, Iowa, in 1885, he received a B. A. degree from Cornell University, and continued his studies at Michigan College of Mines, Houghton, Mich., graduating with a mining engineering degree in 1912. He was superintendent, Fort Montgomery Iron Corp., Highland Falls, N. Y. from 1920-1939. Later he did consulting work as a licensed engineer and land surveyor in New York.

Stephen L. Goodale (Legion of Honor 1904) died in his home on January 17. A native of Saco, Me., where he was born in 1875, he was educated at Colorado College, Colorado Springs, Colo. His long and active career included teaching at the University of Pittsburgh, where he was professor of metallurgy.

George B. Pryde (Member 1925) died Aug. 21, 1956, at the age of 84. A native of Gauldry, Scotland, he attended the University of Wyoming. He began his career as night foreman, Northern Pacific Coal Co., later becoming mine superintendent, Riverside Coal Co. In 1924 he was promoted to vice president and general manager, Union Pacific Coal Co. which he had joined in 1908.

David Avery (Member 1917) died last October in his native land, Australia. Born in 1871, he received a Master of Science degree in chemistry and physics from Melbourne University. Mr. Avery was head of the chemistry department, Melbourne Technical School from 1898-1910. Later he opened his own consulting office specializing in treatment of lead ores, including flotation work, byproducts, and plant economics.

Necrology

Date Elected	Name	Date of Death
1948	John C. Andersen	Dec. 12, 1956
1928	Harold B. Bernard	Unknown
1947	Charles W. Binckley	Dec. 12, 1956
1902	Russell T. Cornell	Feb. 16, 1957
1942	Daniel M. Coxe	Unknown
1944	Francis J. Dohrer	Mar. 30, 1956
1956	Tom Duckels	Unknown
1947	Wordsworth C. Elliott	Sept. 1956
1936	W. L. Goldston, Jr.	Jan. 22, 1957
1928	R. C. Good	Jan. 11, 1957
1950	Joseph Francis Joy	Feb. 19, 1957
1928	C. D. King	Mar. 24, 1957
1918	George D. Louderback	Jan. 27, 1957
1936	Ernest J. Maust	Unknown
1919	Donald Hugh McDougall	Dec. 4, 1956
1947	James W. Morgan	Feb. 1, 1957
1918	A. C. Munro	Nov. 15, 1956
1915	Harold M. Smyth	Dec. 19, 1956
1915	J. D. Sperr	Nov. 21, 1956
1913	Robert T. Walker	Jan. 24, 1957
1900	Haarlem E. West Legion of Honor	Jan. 9, 1957

MEMBERSHIP

Proposed for Membership
Mining Branch, AIME

Total AIME membership on Feb. 29, 1957, was 27,101; in addition 2,938 Student Associates were enrolled.

ADMISSIONS COMMITTEE

R. B. Caples, Chairman; F. A. Ayer, Vice-Chairman; A. C. Brinker, R. H. Dickson, C. R. Dodson, R. B. Fulton, T. D. Jones, F. W. Hanson, Sidney Rolle, F. T. Sisco, O. B. J. Fraser, F. W. McQuiston, Jr., A. R. Lytle, L. P. Warriner.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

Members

John J. Baker, Buhl, Minn.
Wm. A. Benson, Ishpeming, Mich.
Joseph H. Birman, Los Angeles
Victor J. Blum, S. J., St. Louis
A. F. Boyd, Grand Junction, Colo.
J. Wm. Bryant, Silver Bay, Minn.
Lazaro Completo, Zambales, P. I.
Fred W. Cook, Concord, Calif.
James W. Dalton, Bartow, Fla.
Charles S. Davis, San Francisco
Raymond C. Derzay, Denver
Walter B. Farnsworth, Newark, N. J.
G. A. Frame, Copper Cliff, Ont., Canada
Ross H. Goodrich, Claremont, N. H.
Kenneth M. Haley, Silver Bay, Minn.
Charles E. Higdon, Denver
Eugene B. Hotchkiss, New York
Frederick T. Jensen, Butternut, Wis.
Donald Kochersperger, Minas Gerais, Brazil
Kelsey C. Lindstrom, Stamford, Conn.
E. Marcel, Nancy, France
F. J. Mecham, Reno, Nev.
Lee R. Messerly, Salt Lake City
William Mrak, Sutton, Alaska
Leonard Parker, Webb City, Mo.
Floyd G. Parrish, Scranton, Pa.
James B. Patch, Lewiston, N. Y.
Edgar K. Pinnick, Grand Junction, Colo.
W. J. Pollin, Salt Lake City
D. A. Pretorius, Bulawayo, Southern Rhodesia
Travis H. Redman, Grand Junction, Colo.
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David R. Shefchik, Hibbing, Minn.
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Coming Events

May 6-8, Institute on Lake Superior Geology, annual meeting, cosponsored by AIME Exploration Subsection, Upper Peninsula Local Section, Michigan Geological Survey, and Michigan Geological Society, Kellogg Center, Michigan State University, East Lansing, Mich.

May 10, AIME St. Louis Section, presidential visit and dinner-dance. Speaker: J. L. Gillson, AIME Vice President.

May 13-16, Coal Convention and Exposition of the American Mining Congress, City Auditorium, Cleveland.

May 16, AIME Utah Local Section. Speaker: A . E. Millar, General Manager, The Anaconda Co., Yerington Mines, Weed Heights, Nev.; subject: *The Yerington Story.* Newhouse Hotel, Salt Lake City.

May 16-18, Geological Soc. of America, Southwestern Section meeting, Morgantown, W. Va.

May 23-24, Lake Superior Mines Safety Council, 33rd annual conference, Hotel Duluth, Duluth.

May 24-25, AIME Central Appalachian Section, spring meeting, Maple Shade Inn, Pulaski, Va.

Sept. 5-7, New Mexico Geological Soc., 8th annual field conference, Durango-Silverton-Ouray area, southwestern Colorado.

Sept. 8-Oct. 9, Commonwealth Mining and Metallurgical Congress, British Columbia to Nova Scotia, Canada.

Sept. 9-12, American Mining Congress, annual convention, Utah and Newhouse Hotels, Salt Lake City.

Sept. 18-21, International Mineral Dressing Congress, Royal Inst. of Technology, Stockholm, Sweden.

Oct. 9-11, ASME-AIME Coal Div., Joint Solid Fuels Conference, Chateau Frontenac, Quebec.

Oct. 15-18, AIME Southeastern States Mining Conference, Hillsboro Hotel, Tampa, Fla.

Oct. 30-Nov. 1, AIME, Rocky Mountain Minerals Conference, Denver.

Nov. 11-14, Society of Exploration Geophysicists, 27th Annual Meeting, Statler-Hilton Hotel, Dallas.

Feb. 16-20, 1958, AIME Annual Meeting, Hotel Statler, New York.

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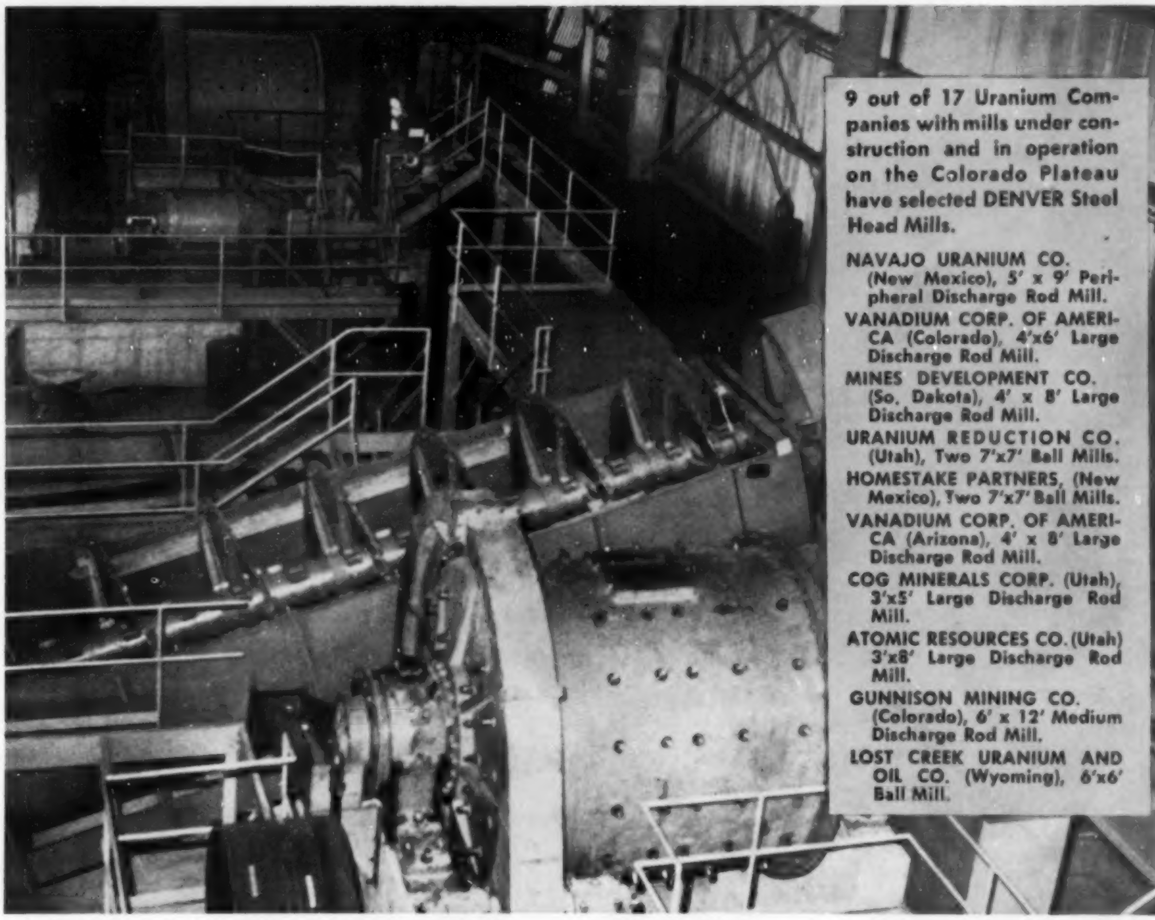

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